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UNEP

THE ADAPTATION GAP

A Preliminary Assessment

REPORT



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UNEP

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REPORT

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GLOSSARY

The entries in this glossary are adapted from definitions provided by authoritative sources, such as the Intergovernmental Panel on Climate Change (IPCC).

Adaptation	In human systems, the process of adjustment to actual or expected climate and its effects in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.
Adaptation assessment	The practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency and feasibility.
Adaptation benefits	The avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures.
Adaptation costs	Costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs.
Adaptation deficit	The gap between the current state of a system and a state that minimizes adverse impacts from existing climate conditions and variability.
Adaptation technologies	The application of technology in order to reduce the vulnerability or enhance the resilience of a natural or human system to the impacts of climate change. Commonly three categories of adaptation technologies are distinguished; hardware, software and orgware.
Adaptive capacity	The combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities (IPCC 2012).
Annex I countries	The industrialised countries (and those in transition to a market economy) that took on obligations to reduce their greenhouse gas emissions under the (UNFCCC).
Baseline	The baseline (or reference) is the state against which change is measured. It might be a current baseline, in which case it represents observable, present-day conditions. It might also be a 'future baseline', which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines.
Climate	Climate in a narrow sense is usually defined as the 'average weather', or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization (WMO).
Climate change	Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity.

Climate (change) scenario	A plausible and often simplified representation of the future climate based on an internally consistent set of climatological relationships and assumptions of radiative forcing, typically constructed for explicit use as input to climate change impact models. A 'climate change scenario' is the difference between a climate scenario and the current climate.
Human system	Any system in which human organizations play a major role. Often, but not always, the term is synonymous with 'society' or 'social system', for example, agricultural system, political system, technological system, economic system.
Climate (change) Impacts	The effects of climate change on natural and human systems.
Mitigation	An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.
Opportunity cost	The cost of an economic activity forgone through the choice of another activity.
Risk assessment	Evaluation of the quantitative or qualitative value of risk related to a concrete hazard. Quantitative risk assessments include two components: the magnitude of the potential loss and the probability that it will occur.
Scenario	A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections but are often based on additional information from other sources, sometimes combined with a 'narrative storyline'.
Technology	The practical application of knowledge to achieve particular tasks that employs both technical artefacts (hardware, equipment) and (social) information ('software', know-how for production and use of artefacts).
Technology transfer	The exchange of knowledge, hardware and associated software, money and goods among stakeholders that leads to the spreading of technology for adaptation or mitigation. The term encompasses both diffusion of technologies and technological cooperation across and within countries.
Uncertainty	An expression of the degree to which a value (for exmaple, the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (such a range of values calculated by various models) or by qualitative statements (for example., reflecting the judgement of a team of experts).
Vulnerability	The propensity or predisposition to be adversely affected.
Welfare	An economic term used to describe the state of well-being of humans on an individual or collective basis. The constituents of well-being are commonly considered to include materials to satisfy basic needs, freedom and choice, health, good social relations, and security.

ACRONYMS

AGF	High-Level Advisory Group on Climate Change Financing
ALP	Adaptation Learning Programme
AR	Assessment Report
COP	Conference of the Parties to the United Nations Framework Convention on Climate Change
CRED	Centre for Research on the Epidemiology of Disasters
CTC	Climate Technology Centre
CTCN	Climate Technology Centre and Network
DAC	Development Assistance Committee of The OECD
DFIs	Development Finance Institutions
EACC	Economics of Adaptation to Climate Change
EbA	Ecosystem-based Adaptation
FAREI	Food and Agricultural Research and Extension Institute
GAN	Global Adaptation Network
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	greenhouse gas
GIS	geographical information systems
HDI	Human Development Index
HFA	Hyogo Framework for Action
IAM	Integrated Assessment Model
IFF	Investment and Financial Flows
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
KARI	Kenya Agricultural Research Institute
LDC	Least Developed Countries
LDCF	Least Developed Countries Fund
LIC	Low Income Countries
MDB	Multilateral Development Bank
MIC	Middle Income countries
NAPs	National Adaptation Plans
NAPAs	National Adaptation Programmes of Action
NEEDS	UNFCCC National Economic, Environment and Development Study
NGO	non-governmental organization
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
OPV	Open Pollinated Varietal rice seed
OWG	Open Working Group
PNACC	National Climate Change Adaptation Plan
PPCR	Pilot Program for Climate Resilience
PSP	Participatory Scenario Planning
RECCS	Regional Economics of Climate Change Studies
RCPs	Representative Concentration Pathways
SCCF	Special Climate Change Fund
SDGs	Sustainable Development Goals
SIDS	Small Island Developing States
SPM	Summary for Policymakers
SREX	Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
SSPs	Shared Socioeconomic Pathways
START	Global Change Systems for Analysis, Research and Training
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WG	Working Group

FOREWORD

THE ADAPTATION GAP —A PRELIMINARY ASSESSMENT

This year's Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Lima, Peru, is a critical step on the path towards realizing the global agreement on climate change to be signed in 2015 and to enter into force in 2020. The global agreement must succeed in binding nations together in an effective global effort that stimulates the faster and broader action urgently required to keep global average anthropogenic warming below 2° Celsius, and enables countries, communities and ecosystems to adapt to the unavoidable risks and impacts of climate change.

With this preliminary assessment of adaptation gaps, it is our hope that UNEP can help inform governments as they prepare their submissions to the Ad Hoc Working Group on the Durban Platform for Enhanced Action and negotiate the global agreement on climate change.

The report has been produced in response to requests by parties for an assessment on adaptation, complementary to the annual Emissions Gap report that UNEP has produced since 2010. The emissions gap reports serve as a sobering assessment of the gap between ambition and reality in relation to how nations are faring towards bringing emissions down to the levels required by 2020 to have a likely chance to keep global average temperature rise this century under 2° Celsius.

This first Adaptation Gap report provides an equally sobering assessment of the gap between adaptation needs and reality, based on preliminary thinking on how baselines, future goals or targets, and gaps between them might be defined for climate change adaptation. The report focuses on gaps in developing countries in three important areas: finance, technology and knowledge.

The analysis shows that there is likely to be a significant adaptation funding gap after 2020 and indicates a key role for the Green Climate Fund in contributing to bridging this gap. The report finds that available global estimates of the costs of adaptation of between US$70 billion and US$100 billion are likely to be a significant underestimate, particularly in the years 2030 and beyond. Indeed national studies indicate that by 2050, costs of adaptation are plausibly four to five times higher than current estimates.

One of the strongest messages of the report is that ambitious and immediate mitigation action is the best insurance against an insurmountable future adaptation gap. Indicative modelling shows that the costs of adaptation could double by 2050 if the world fails to reduce emissions to the levels required to limit global annual temperatures to rise less than an extra 2° Celsius and continues current high-emission trajectories that are likely to lead to a global average temperature increase of around 3.7 to 4° Celsius.

The report's review of current adaptation-related finance flows reveals a positive story over recent years. Public adaptation-related finance—based on available data to date—is estimated at around US$24.6 billion in 2012/13, of which 88 per cent was invested in non-OECD countries. This represents a large increase over recent years and indicates how climate change concerns are increasingly integrated in sustainable development, Green Economy and climate resilient development strategies.

The analysis indicates that in the short to medium term another key issue is to accelerate the diffusion of appropriate technologies for adaptation. There are, however, also situations where international technology transfer is critical, for example for new or improved crop varieties and water use efficiency techniques.

In relation to knowledge gaps, the report highlights that there is considerable scope for using existing knowledge on climate change and adaptation more effectively. Integrating knowledge from different sources and making it available to decision-makers at different levels is one of the most important knowledge needs. The successful uptake of existing knowledge depends on communication between researchers and decision-makers, the effective tailoring of knowledge to the specific context and constituency, and its translation into formats or languages required by decision-makers.

This preliminary adaptation gap assessment underlines the importance of comprehensive inclusion of adaptation as part of the global agreement on climate change and indicates target areas for further efforts. At the same time, it serves as a powerful reminder that strong and immediate mitigation action is a crucial precondition for avoiding unmanageable climate risks and impacts.

Achim Steiner
UN Under-Secretary-General,
UNEP Executive Director

EXECUTIVE SUMMARY

Even if emissions of greenhouse gases are stabilised at a level that is consistent with the ultimate goal of the United Nations Framework Convention on Climate Change (UNFCCC), both the risks and the impacts of climate change are expected to increase significantly in coming decades. Adopting a strategic framework for adaptation—with clearer goals and targets—would help set the direction for and track progress on adaptation universally and in relation to the ongoing negotiations under the UNFCCC. In this context, adopting an adaptation gap approach with its focus on targets—as well as on the potential for, and limits to adaptation—could be useful.

This report is being published in response to requests made to the United Nations Environment Programme (UNEP) by different parties to provide a preliminary assessment of adaptation gaps to complement information presented in the emissions gap reports UNEP has been producing since 2010. The emissions gap reports analyse the estimated gap in 2020 between emission levels consistent with the goal of keeping global average temperature increase in this century below 2°C above pre-industrial levels, and projected levels if emission reduction pledges by parties are met. Parties have found the emissions gap reports useful in helping inform their discussions at the annual Conference of the Parties (COP) to the UNFCCC.

The report focuses on developing countries, where adaptation needs are anticipated to be the highest and adaptive capacity is often the lowest. The main emphasis is on the period from 2010 to 2050, as the short- to medium-term is considered the most relevant period of time for framing adaptation decisions and actions.

FRAMING THE ADAPTATION GAP

Estimating the adaptation gap is far more challenging than calculating the emissions gap, as there is no globally agreed goal or metrics for adaptation, and adaptation is a response to specific climate risks and impacts often local in nature and vary over time. Key challenges in creating a framework for identifying adaptation gaps include: (i) the framework should be applicable across the globe on different spatial scales and across many sectors and risks; (ii) it should adequately capture current gaps in adapting to existing climate conditions and variability, as well as future gaps arising from the impact of increased climate change; and (iii) it should acknowledge, and allow for, differences in societal values and preferences with regards to determining a 'desirable' level of adaptation at local, national, regional and global levels.

The proposed framework for defining adaptation gaps facilitates the identification of **the present and future potential for, and limits to, adaptation, and the discussion of adaptation targets**.

Definition

The adaptation gap can be defined generically as the difference between actually implemented adaptation and a societally set goal, determined largely by preferences related to tolerated climate change impacts, and reflecting resource limitations and competing priorities.

There are big differences in the potential for reducing the risks and impacts of climate change through additional adaptation now and in the near term. These, depend on both climate and non-climate stressors. The 5th Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) gives examples of representative key risks in different regions. These highlight that **finance, technology and knowledge** (in relation to improved management practices) are key determinants for realizing adaptation potential, making it possible to reduce risks and impacts in both the short- and long-term. They point to a significant overlap between adaptation and development issues and options, underlining the importance of adopting an integrated approach.

Finding ways of measuring the adaptation gap so that progress towards reducing it can be monitored is a major challenge. The choice of definition of the adaptation gap—and the metrics used to track progress towards closing it—will ultimately depend on the purpose for it, as societal preferences about it will vary. The latter represents an additional obstacle with regards to the measurement of a global adaptation gap. A global goal or target could be supplemented by sub-goals or targets flexible enough to be appropriate at regional, national, sector and lower levels, allowing for the consideration of multiple dimensions and objectives.

THE FUNDING GAP

There is likely to be a major adaptation funding gap after 2020 unless new and additional finance for adaptation becomes available. This conclusion is based on an analysis of existing global, sectoral and national estimates of the costs of adaptation, against an assessment of levels and trends in public adaptation finance flows. The Green Climate Fund could play a key role in bridging the adaptation funding gap.

The 5th Assessment Report by the IPCC says that **existing global estimates of the costs of adaptation in developing countries range between US$70 billion and US$100 billion a year globally by 2050**. The findings of this review suggest that these values are likely to be a significant underestimate, particularly in the period after 2030. **At a minimum, the costs of adaptation are likely two-to-three times higher than the estimates reported thus far**, and plausibly much higher than this towards 2050. National-level studies indicate far higher global cost figures than global-level studies: towards 2050, costs could be as much as four to five times higher than the estimates reported in global-level studies. This conclusion is also supported by a methodological review of the global-level studies, which reveals that global-level studies provide only partial coverage of sectors and impacts, do not factor in uncertainty or policy costs, and assume high levels of greenhouse gas emission reductions.

> **Definition**
>
> **The adaptation funding gap can be defined and measured as the difference between the costs of meeting a given adaptation target and the amount of finance available to do so.**

Adaptation costs and finance needs are emissions-dependent and will rise more quickly under higher emission scenarios—that is, under a 4°C rather than a 2°C pathway. Indicative modelling results highlight that compared to a 2°C pathway costs under a 4°C pathway could potentially double around mid-century. This is because the sooner the 2°C threshold is exceeded, the higher the rate of climate change, and the greater the levels of anticipatory adaptation.

Adaptation needs are not equally distributed. In relative terms, **least developed countries (LDCs) and small island developing states (SIDS) are likely to have much higher adaptation needs**, and the failure to implement early adaptation in these regions will have a disproportionate impact, thus widening the current adaptation gap.

The amount of public finance committed to activities with explicit adaptation objectives ranged between US$23 billion and US$26 billion in 2012–2013, of which 90 per cent was invested in developing countries. These estimates are a combination of Official Development Assistance (ODA) and non-ODA finance by governments; Climate Funds earmarked for adaptation; and commitments by Development Finance Institutions. The latter contributed US$22 billion, or 88 per cent, of the total; bilateral adaptation-related aid commitments by government members of the Organization for Economic Co-operation and Development (OECD) provided 9 per cent; the remaining 2 per cent came from adaptation dedicated Climate Funds.

There is evidence that **financial commitments to adaptation objectives have increased in recent years across all sources of finance but, even so, scaling up adaptation finance flows remains a pressing priority**. There has been a significant increase in adaptation dedicated Climate Funds since 2003. Bilateral adaptation-related aid commitments by members of the OECD Development Assistance Committee (DAC) furthermore indicate that adaptation is **increasingly mainstreamed** in development cooperation activities. Nonetheless, the analysis underscores the need for new, predictable and additional sources of funding to bridge the adaptation gap. Building on the work of the United Nations Secretary General's high level Advisory Group on Climate Change Financing, the report underlines the potential for innovative sources in mobilizing funding for adaptation in developing countries.

The funding gap analysis **underestimates the total adaptation finance flows** as data limitations and methodological challenges that prevent the inclusion of the **contribution of the private sector and domestic public budgets in developing countries** directly carrying out and supplying adaptation measures in response to the early risks and impacts of climate change. Furthermore, no attempt has been made at indicating the share of the adaptation funding gap to be covered through international and domestic finance flows or to make a distinction between funding for development gaps and funding for adaptation gaps.

THE TECHNOLOGY GAP

It is difficult to define and measure the adaptation technology gap separately from the adaptation gap because of the considerable overlap between the definition of technologies for adaptation and the definition of adaptation. However, we can **identify perceived gaps by the countries based on available technology needs assessments**, and requests to technology support mechanisms. These gaps are identified both in terms of technological maturity (traditional, modern, high technology) and in terms of area of effort (transfer, diffusion, innovation).

Experience with technologies for adaptation has shown that the most **successful efforts at promoting the transfer and diffusion of adaptation technologies are those that meet a number of human needs in addition to providing climate benefits.** Moreover, they are firmly grounded in the broader socio-cultural, economic, political and institutional contexts of the location where the technology is used. Simply stated, the best technology may be that which serves a variety of purposes above and beyond the climate-related. Not least, all evidence highlights that adaptation technologies are needed across all socio-economic sectors. At present, the development and transfer of adaptation technologies occurs mainly in the context of the implementation of adaptation projects and programmes, and the main sources of financing are expected to come from adaptation funding sources, such as the Green Climate Fund.

Definition

The adaptation technology gap can be defined in terms of perceived gaps by countries, based on available technology needs assessments and requests made to technology support mechanisms.

Most technologies for adaptation needed in the short- to near-term already exist and are often available within a country, but major barriers to their further uptake remain. Additional efforts have to be made to accelerate the diffusion and uptake of critical technologies. An analysis of recent Technology Needs Assessments and Technology Action Plans indicates that, in the area of adaptation today, technology transfer as such is not the key obstacle for closing the adaptation technology gap—rather dissemination and uptake pose more important obstacles. Governments can facilitate the flow of technologies within countries through incentives, regulations and the strengthening of institutions.

International technology transfer for adaptation is also critical. Areas where the international transfer of technologies is particularly important include improved crop varieties, water use efficiency techniques, and monitoring systems.

Research and development have a significant role to play in helping adjust existing technologies to local conditions, not least through innovation in areas where existing technologies—such as insurance solutions, high yielding crop varieties, or water use efficiency appliances—are insufficient to meet fundamental adaptation challenges. Sharing experiences between countries could contribute substantially to closing the adaptation technology gap in regions facing similar challenges.

Evidence shows that technological change is linked to institutional change. As a result, **institutional strengthening can support the innovation and adoption of advanced technologies**. Specifically, reinforcing the mandate and capacities of the relevant existing and new institutions to include the development, transfer and diffusion of adaptation technologies can help close the adaptation technology gap. To this end, more targeted evidence on the ability of technology options to reduce climate risks and associated costs is required from local to global level.

THE KNOWLEDGE GAP

The report focuses on three types of knowledge gaps that, if addressed, could make significant contributions towards reducing the overall adaptation gap, both in the short- and medium-term. They are: missing or incomplete knowledge (gaps in knowledge production); inadequate linkages between different bodies of knowledge (gaps in knowledge integration); and limited diffusion and translation of knowledge to decision makers (gaps in knowledge transfer and uptake).

Definition

Knowledge gaps can be framed in the context of bridging either the generic adaptation gap or a specific adaptation gap. While they are difficult to quantify, it is possible to set specific and measurable targets for addressing them.

There is considerable scope for using existing knowledge on adaptation more effectively. **Integrating knowledge from different sources and making it available to decision-makers at different levels is arguably the most important knowledge need.** Connecting and integrating different communities and approaches is often challenging, which explains the shortage of much-needed initiatives facilitating the bridging of knowledge systems. To make it accessible and useable for decision-makers, knowledge must also be filtered and synthesized. The successful uptake and use of knowledge requires communication and co-exploration between researchers and decision-makers, the effective tailoring of knowledge to the specific context

and constituency, and its translation into the formats or languages most suited to decision-making.

For many regions and countries, there is a lack of systematic identification and analysis of adaptation knowledge gaps, and there are few initiatives focused on addressing this. The consideration of knowledge gaps should be integrated more explicitly in project and programme framing and design, involving all stakeholders. This would help ensure that the knowledge produced responds better to user needs and identified knowledge gaps, and is relevant and usable for decision making.

Some of the most commonly cited gaps in the knowledge base that could be bridged in the short term concern the opportunities and constraints of various adaptation options and cost–benefit analysis of adaptation strategies. **In this context, additional experience with the monitoring and evaluation of adaptation actions would help improve the effectiveness of such actions**. A semi-standardized documentation of project experience to support comparison and effective linking with national plans, objectives, priorities and monitoring processes would go a long way towards meeting that. Similarly, collaborative efforts connecting researchers, practitioners and other stakeholders at different levels could greatly help bridge specific knowledge gaps.

Due to uncertainties associated with climate change and its impact, adaptation decisions will continue to be made with imperfect knowledge. **A repository of adaptation options for specific regions and on different levels that can be integrated in development decisions is currently missing and could play a pivotal role in informing development decisions.** The systematic evaluation of development efforts could help ensure that they are sustainable and do not inadvertently increase climate change risks.

SUMMING UP

It is often stated that adaptation is local, while mitigation is global. Although true in some ways, the preliminary analysis in this report highlights that adaptation challenges also require global action. It is clear that adaptation is often a response to specific climate risks at a given time and in a given context. Nonetheless, the magnitude and unequal distribution of the adaptation challenge and the similarities between the types of climate risks and the choice of adaptation responses communities, sectors, countries and regions face, indicate the relevance of a global framework. Clearer goals, targets and metrics would help set the direction for adaptation action and would facilitate tracking progress towards meeting those goals and targets.

As illustrated in the report, the multiple dimensions of adaptation make it challenging to come up with a single goal and measure for adaptation. A plausible approach may therefore be to establish goals and targets in key areas. The Millennium Development Goals, the new Sustainable Development Goals, and the process for the development of a post-2015 framework for disaster risk reduction are examples of relevant approaches where goals and targets are set, while accommodating differences in capacity, needs and preferences.

This report focuses on finance, technology, and knowledge as key levers to address current and future adaptation gaps. Other gaps, including in capacity and governance, are equally important to consider. Moreover, there is complex interaction between various gaps. As Chapter 2 and 3 of the report underline, while increased adaptation finance flows is a prerequisite to address adaptation gaps, they may have limited effect on reducing climate risks and impacts if the absorptive capacity required for effective use of these resources is low.

The report points to a number of areas for further action and future analysis. Cross-cutting issues relate to transparency and comparability of methodologies; establishing appropriate metrics for assessing adaptation needs and gaps; comprehensive monitoring and evaluation of adaptation; and establishing a central repository of information on adaptation options and action. In addition, the chapters of the report highlight a need to address the challenges of existing estimates of the costs of adaptation; expand the information on private and domestic adaptation finance; provide more targeted analysis of the potential for technologies to reduce climate risks and impacts in various sectors; and provide systematic analysis of knowledge gaps and how to bridge them. The intention is to provide fuller analysis of some of these aspects in future reports.

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CHAPTER 1

INTRODUCTION

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Countries, communities, people and ecosystems around the world are already struggling to cope with the adverse impacts of existing climate conditions and variability. Today there is a gap between the actual level of climate impacts and the level that could be achieved with more comprehensive adaptation efforts. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (2014a, 2014b) documents that climate risks and impacts will increase significantly in the coming decades, even if emissions of greenhouse gases are stabilized at a level that is consistent with the temperature goal of the United Nations Framework Convention on Climate Change (UNFCCC).[1] The increase in climate risks and impacts will be felt more acutely in developing countries, and even more so in the poorest and most vulnerable among them, where there is a need to scale up adaptation efforts substantially, now and in the future. A better understanding of the size and nature of future risks and impacts and how they can be effectively addressed is needed universally as well as in the context of the ongoing negotiations under the UNFCCC.

The United Nations Environment Programme (UNEP) has produced annual emissions gap reports since 2010 that document the gap between climate change mitigation ambition and action. These reports inform governments—in advance of the annual Conference of the Parties (COP) to the UNFCCC—on the estimated gap in 2020 between emission levels consistent with the 2 °C limit and projected levels if emission reduction pledges by parties are met.[2] This adaptation gap report is produced in response to requests made to UNEP by different parties to provide a preliminary assessment of adaptation gaps, as a complement to the information presented in the emissions gap reports.

Framing and assessing an adaptation gap is, however, very different to framing and assessing the emissions gap. Unlike mitigation—where there is a global goal and gaps can be analysed using the single metric of tonnes of carbon dioxide equivalent—there is no quantifiable goal or target for adaptation at the global level against which an adaptation gap can be defined, and no simple, common metric that can be used to assess it. In addition adaptation is a response to specific climate risks and impacts, which are often local in nature and vary over time. This makes it challenging to provide a single, global estimate of the adaptation gap. With this first adaptation gap report, UNEP—in collaboration with 28 experts from 19 leading research institutions—provides preliminary thoughts and indicative findings on how adaptation gaps can be meaningfully defined and assessed. These questions are addressed at a conceptual level in Chapter 2. The subsequent chapters focus on adaptation gaps in three important areas: finance (Chapter 3), technologies (Chapter 4), and knowledge (Chapter 5). The intention is for the report to contribute to the debate on the level of ambition of the international climate change regime, while providing a foundation for the development of future and more comprehensive adaptation gap reports.

The report focuses on developing countries, where adaptation needs are anticipated to be the highest and adaptive capacity is often the lowest. The report emphasizes the period 2010–2050, as the short- to medium-term is considered most relevant for framing adaptation decisions and action.

1 To keep the increase in global mean temperatures below 2 °C by 2100 compared to pre-industrial levels.

2 UNEP has published five emissions gap reports thus far (UNEP 2014a, 2013a, 2012, 2011, 2010), which provide not only estimates of the emissions gap, but also suggest ways to bridge it.


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CHAPTER 2

A FRAMEWORK FOR IDENTIFYING AND MEASURING ADAPTATION GAPS

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2.1 INTRODUCTION

The terms 'adaptation gaps' and 'adaptation goals' are appearing with increasing frequency in the literature and in the context of the UNFCCC, but there are no clear definitions or consistent use of these terms. The purpose of this chapter is to present and discuss options for defining and measuring an adaptation gap—or gaps—that can serve as a basis for future elaboration as well as for the subsequent chapters of this report on adaptation funding, technology and knowledge gaps.

Adaptation goals or targets[1] are important concepts in relation to adaptation gaps, as one of the more likely ways of measuring an adaptation gap is as the difference between an actual or anticipated state and some pre-agreed adaptation target. These concepts are, in turn, closely linked to the notion of 'adaptation needs', interpreted in the recent IPCC report as the gap between what might happen under climate change and 'desired outcomes' (Noble *et al.* 2014). The concept of adaptation needs is also central to the National Adaptation Plan process under the UNFCCC, established to enable countries to formulate and implement national adaptation plans (NAPs) as a means of identifying medium- and long-term adaptation needs and developing and implementing strategies and programmes to address those needs (UNFCCC 2014a). Similarly, it is relevant to the ongoing discussions on options for submitting information regarding Intended Nationally Determined Contributions (INDCs) for adaptation as part of the comprehensive road map towards the universal agreement on climate change to be adopted in 2015 for the period beyond 2020 (UNFCCC 2014b).

Adaptation and adaptation gaps are linked, often inextricably, with development. This is broadly recognised, for example, in the National Adaptation Plan processes that are expected to be integrated with national development planning. Another clear example is the increasing emphasis on mainstreaming adaptation in development activities and related finance, as Chapter 3 of this report illustrates. Similarly, adaptation targets should be considered in conjunction with the ongoing work in developing indicators and targets for the Sustainable Development Goals (UN Open Working Group 2014).

1 The term 'target' is adopted for the purposes of this report.

2.2 FROM EMISSIONS GAPS TO ADAPTATION GAPS

UNEP has produced a series of emissions gap reports since 2010. These analyse the estimated gap in 2020 between emission levels consistent with the goal of keeping the rise in global average temperatures to less than 2°C above pre-industrial levels, and projected levels if emission reduction pledges by parties are met (UNEP 2014a, 2013a, 2012, 2011, 2010). As noted in the Introduction to this report, identifying and measuring adaptation gaps is very different from identifying and measuring emissions gaps given the lack of a quantifiable goal or target for adaptation at the global level, and the lack of a simple, commonly agreed metric to measure it, both of which reflect the multi-dimensional nature of climate change impacts and adaptation.

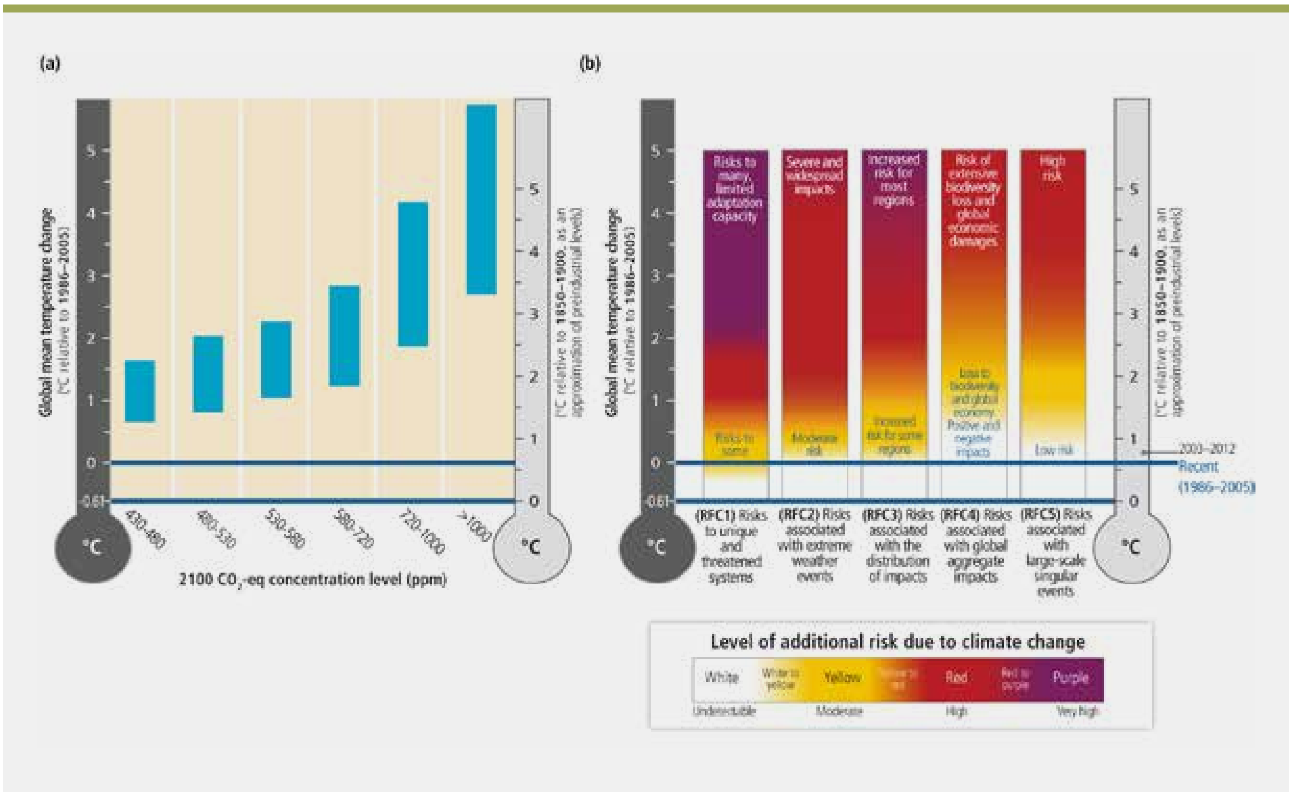
The UNEP Emissions Gap Report (2013a) recognizes that there are fundamental differences between defining and measuring emissions and adaptation gaps: *"While the emissions gap indicates the quantity of greenhouse gas emissions that need to be abated, the adaptation gap could measure vulnerabilities which need to be reduced but are not accounted for in any funded programme for reducing adaptation risks. Alternatively, it could estimate the gap between the level of funding needed for adaptation and the level of funding actually committed to the task."* (UNEP 2013a, p. 2).

The recent UNEP supported report, *Africa's Adaptation Gap (2013b)*, defines the term adaptation gap as "*the difference between what is needed in terms of adaptation and what is currently realised in terms of, among others, access to funds, capacity building, and monitoring and evaluation systems*." (UNEP 2013b, p.2). Thus, these reports recognize that several dimensions of adaptation gaps might be of interest.

In addition adaptation is a response to specific climate risks and impacts, which are often local in nature and vary over time and with emission trajectories. The latter implies that the size and nature of adaptation gaps is emissions dependent.

Figure 2.1 illustrates the emissions dependency of adaptation gaps by linking emission trajectories to climate outcomes in terms of temperature changes (Figure 2.1(a)), and illustrating how these in turn affect climate risks and impacts (Figure 2.1(b)). The figure illustrates that global mitigation ambition has direct implications for climate risks and impacts, and thus for adaptation needs and gaps.

Figure 2.1: Linking emission trajectories to climate outcomes (a) and impacts and risks (b)



Source: Oppenheimer et al. (2014, Figure 19-7). Note: (a) The projected increase in global mean temperature in 2100 compared to pre-industrial and recent (1986–2005), indicating the uncertainty range resulting both from the range of emission scenario projections within each category and the uncertainty in the climate system. (b) The dependence of risk associated with the Reasons for Concern (RFCs) on the level of climate change[2]. The colour shading indicates the additional risk due to climate change when a temperature level is reached and then sustained or exceeded. The shading of each ember provides a qualitative indication of the increase in risk with temperature for each individual "reason."

This is particularly important in the medium- to longer-term, where the full effects of different emission trajectories will be realized in terms of atmospheric and temperature changes and associated changes in risks and impacts. In this report we consider the timeframe from the present to mid-century as this is considered the most relevant timeframe for adaptation decision-making[3].

The main focus is on the risks, impacts and adaptation gaps associated with emission trajectories that achieve the goal of keeping global average temperature increase in this century below 2°C above pre-industrial levels.

2 'Reasons for Concern' are elements of a classification framework first developed in the IPCC Third Assessment Report (McCarthy *et al.* 2001). This framework aims to facilitate judgments about what level of climate change may be "dangerous" (in the language of Article 2 of the UNFCCC, whereby the goal is stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system) by aggregating impacts, risks, and vulnerabilities.

3 It is noted, however, that longer timeframes are relevant for some climate-sensitive investment decisions, particularly related to infrastructure.

2.3 A GENERIC FRAMEWORK FOR IDENTIFYING ADAPTATION GAPS

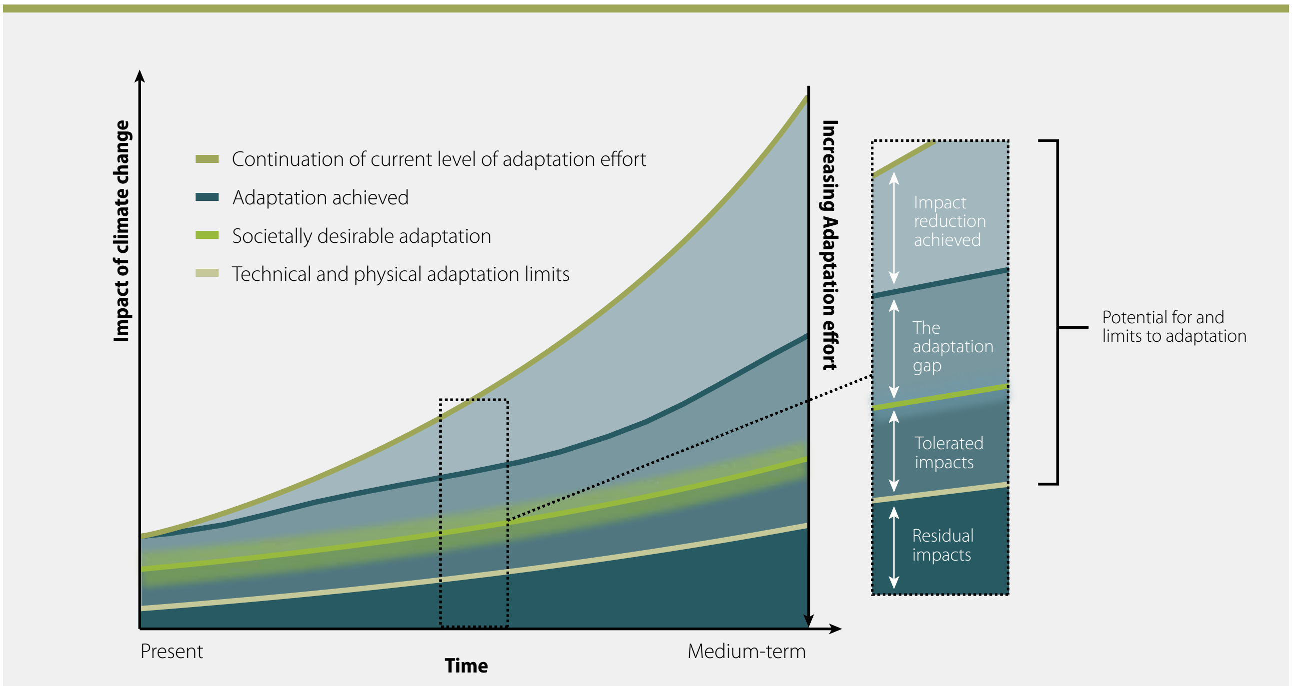
A key challenge in creating a framework for identifying adaptation gaps is that it should be applicable across the globe at different spatial scales and across many sectors and risks; that it should adequately capture current gaps (see Box 2.1) in adapting to existing climate conditions and variability, as well as to the development of future adaptation gaps due to climate change; and that it should acknowledge and allow for differences in societal values and preferences in determining a 'desirable' level of adaptation across local, national, regional and global level.

The simple, generic framework for identifying adaptation gaps proposed here builds on material in the recent IPCC report (Chambwera *et al*. 2014), describing how different constraints narrow adaptation from the space of all possible adaptations to what can and will be done. The framework can be applied at various scales (global, national, regional, sector, city, or community) and can be measured using a wide range of indicators and metrics. In fact, a core decision to be made is which metrics might best measure impacts of climate on the target group or sector and adaptation targets expressed in that same metric. We return to this aspect later in the chapter.

The generic framework is illustrated in Figure 2.2. It summarizes the main ideas related to an adaptation gap, its development through time, and the establishment of adaptation targets. It is taken to represent a timeframe from the present to about mid-century and assumes that the world follows an emission pathway that limits global average anthropogenic warming in this century to below 2°C above pre-industrial levels. It could also be applied to higher or lower emission pathways, which would shift the lines in Figure 2.2 and affect climate change impacts and risks over time as highlighted in the previous section. However, these effects would be more significant for longer timeframes than the one considered and the focus here is how impacts can be reduced through adaptation efforts.

The vertical axis on the left hand side of the figure indicates the impacts of climate change (which can be interpreted as 'realized climate risks'). These are expected to increase over time, partly due to committed changes from past and current emissions, but they can be reduced by increased levels of adaptation effort, as indicated by the downward pointing arrow on the right hand side of the figure. There are, however, physical and technical limits to how much additional adaptation efforts can reduce climate impacts; for example from damage from extreme floods, or by protecting low lying atolls from storm surges and sea level rise, or reducing the impacts of increased heat stress on outside activities. Some ecosystems, for example coral reefs, will change irreversibly as greenhouse gas concentrations in the atmosphere and temperatures rise. These limits are represented by the bottom line 'Technical and physical

Figure 2.2: A framework for identifying adaptation gaps



Source: Authors. See text for an explanation.

adaptation limits', with the area below this line representing residual impacts. Technological advances may lower these impacts but cannot eliminate them, and in many cases they are likely to increase with further climate change.

Few societies are able, or prepared, to commit the resources to adaptation required to bring climate change risks and associated impacts down to the technical and physical limits to adaptation. They may consider these options too expensive and may prefer to allocate resources to other priorities and tolerate a higher level of risk of climate impacts. For example they may prefer to improve their welfare through investment in health or education, or reduce other risks such as from earthquakes or conflicts. A city currently outside the tropic storm zone may decide to bear the risks of low probability, high impact storms rather than the up-front costs of adapting to them, or the minor losses associated with occasional flooding events rather than bear the cost of a large infrastructure solution. In Figure 2.2 this is represented by the line 'Societally desirable adaptation', which best represents an 'adaptation target'. The adaptation target line is blurred as preferences will vary between different elements of society depending on the cost effectiveness of adaptation actions; on who bears those costs and receives the benefits; and on the attitude to accepting and bearing residual risks (financial, to property, to ecosystems, and to lives and livelihoods). The adaptation target will also depend on the level of economic development, as this influences the resources that can be allocated to adaptation.

The actual level of adaptation achieved will usually be less than the societally desirable level as indicated by the lines in Figure 2.2. This arises from market failures as well as from practical, political, or institutional constraints (Chambwera *et al*. 2014). The difference between the societally desirable level of adaptation and that actually implemented may be taken to represent the adaptation gap. The figure illustrates a situation where there is a current adaptation gap. As indicated here, both the societally desirable adaptation and actual level of adaptation achieved are linked to development (see Box 2.1).

The upper line in Figure 2.2 represents a counterfactual, or business-as-usual, situation where current levels of adaptation effort are continued. If additional adaptation is not undertaken, the adaptation gap can be represented by the difference between the counterfactual and the societally desirable adaptation effort. The difference between the counterfactual and the technical and physical limits to adaptation, indicate the potential and limits for additional adaptation - compared to continuation of current levels - to reduce climate change risks and impacts.

It is important to note that Figure 2.2 is a purely conceptual illustration of climate change impacts, adaptation possibilities and constraints, and adaptation targets and gaps over time. The position and shape of the lines in the figure do not represent an actual adaptation gap. The following sections add practical perspectives to the framework, focusing first on regional examples of the potential for and limits to adaptation, and then outlining options and issues related to establishing targets and metrics necessary for measuring and tracking progress on adaptation gaps.

Box 2.1: Adaptation gaps, adaptation deficits and development

Many, if not most countries, cities or communities are not adequately adapted to existing climate risks, meaning in other words there is a current adaptation gap. In the literature, this current gap is referred to as the adaptation deficit (see Burton 2004, Burton and May 2004). In this report we define the current adaptation gap as the difference between the actual adaptation achieved and a societally desirable level of adaptation, which is in line with Burton (*ibid.*) and others. However, the IPCC defines the adaptation deficit as "The gap between the current state of a system and a state that minimizes adverse impacts from existing climate conditions and variability" (IPCC 2014c), which would imply that the gap is measured against the technical and physical limits to adaptation in Figure 2.2. To maintain consistency, we will refer to current adaptation gaps only.

Regardless of the definition used, the current adaptation gap measured by the number of people affected by climate related risks is much larger in low and middle income countries, leading some to suggest that the adaptation deficit is really part of a larger "development deficit" (World Bank 2010). Delay in action in both mitigation and adaptation will increase this deficit (Noble *et al.* 2014) adding to the adaptation gap. In the process of building future adaptive capacity it is important to reduce the current adaptation gap along with designing effective risk management and adaptation strategies to address the adverse impacts of future climate change (Hallegatte 2009).

2.4 REGIONAL AND CONTEXT SPECIFIC DIMENSIONS OF ADAPTATION GAPS

Knowledge regarding the potential for and limits to adaptation is important to inform decision-making related to setting targets for adaptation. Here we briefly look at some examples of the potential for and limits to adaptation for key risks at the regional level. As noted in the beginning of the chapter, climate risks and impacts are generally location and context specific. In fact, a key challenge in assessing and addressing adaptation gaps at a global level is to find appropriate ways to 'aggregate' gaps - and actions to bridge them - across the scale from local to global. Identifying and measuring adaptation gaps at, for example, regional level or by country groups would facilitate identifying and measuring global adaptation gaps (Lamhauge *et al*. 2012).

The latest IPCC report (IPCC 2014b, 2014d) identifies a number of representative key risks for each region of the world and analyzes risk levels now and in the future for each of these representative key risks, based on expert judgment[4]. Risk levels are assessed for two levels of adaptation effort that allow comparison with the adaptation gap framework of this chapter: a continuation of adaptation at current level and a 'highly adapted' level, representing the potential for and limits to adaptation.[5]

Figure 2.3 shows some of the IPCC examples of representative key risks for developing country regions and the potential for and limits to reducing them through adaptation now and in the near-term (2030-2040). The figure provides a more tangible illustration of the points made in the previous section where the framework for identifying adaptation gaps was described. The bars indicating risk levels and the potential for adaptation correspond to a cross-section of Figure 2.2 at the relevant points in time (present and 2030-2040), where only residual impacts and potential for and limits to adaptation are considered (see the right hand side of Figure 2.2).

Figure 2.3 illustrates that there are wide differences in the potential for reducing climate change risks and impacts through additional adaptation now and in the near term, and that in most cases these depend on both climate and non-climate stressors. An important exception is when risks relate to ecosystems and their level prevents ecosystem adaptation as in the case of coral reefs in Figure 2.3.

The figure also highlights that finance, technology and knowledge, for example relating to improved management practices, is key to realizing the potential for adaptation to reduce risks and impacts. These areas are the focus of the subsequent chapters of the report.

Finally, the figure illustrates that there is a significant overlap between adaptation and development issues and options, underlining the importance of adopting an integrated approach.

4 The IPCC (2014d) considers risk levels for three timeframes: present, near-term (2030-2040) and long-term (2080-2100). In line with the framework and timeframe adopted for this report, only present and near-term are considered in this Chapter. The identification of key risks used the following specific criteria: large magnitude, high probability, or irreversibility of impacts; timing of impacts; persistent vulnerability or exposure contributing to risks; or limited potential to reduce risks through adaptation or mitigation (IPCC 2014d).

5 Note that it is unclear whether the "highly adapted" level of the IPCC (2014b) corresponds to the technological and physical limits to adaptation or societally desirable adaptation in Figure 2.2.

2.5 KEY METHODOLOGICAL CONSIDERATIONS FOR MEASURING ADAPTATION GAPS

The generic framework for identifying adaptation gaps outlined in this chapter acknowledges that key risks, risk levels and associated impacts vary across communities, sectors, countries and regions, and over time, reflecting differing socio-economic development contexts and pathways; vulnerability and exposure to hazards; adaptive capacity; and risk perceptions. Framing and measuring an adaptation gap is likely to be less difficult at community, subnational or sector level, than at national, regional or global level. A key challenge for establishing global adaptation gaps is to identify, agree to and adopt a consistent approach to identifying current adaptation efforts, setting adaptation targets and selecting metrics that allow for an aggregation or comparison of these gaps across scale.

2.5.1 SETTING ADAPTATION TARGETS

Global adaptation targets would allow adaptation to be considered in a broader strategic framework, rather than primarily in specific places or regions. This chapter has highlighted the importance of targets as a means to set the direction for and track progress on adaptation. More generally the setting of adaptation targets is highlighted as a core step in documents and guidance dealing with planning for adaptation to climate change. To illustrate, the recent guidance document for the preparation of NAPs (LEG 2012) has stakeholder engagement in the collective development of adaptation goals as its first step in developing an adaptation framework and roadmap. However, many existing adaptation efforts, including under the UNFCCC, have relatively open ended targets, such as "to improve the resilience to climate change" or "to increase the adaptive capacity". There is increasing focus on the need for 'SMART' adaptation targets (that is targets that are Specific, Measurable, Achievable, Relevant and Time frame defined. See for example Niemeijer and de Groot (2008)). All these criteria are pertinent to setting adaptation targets and for reporting on adaptation gaps, with particular emphasis on measurement and specificity. With the expected substantial increase in adaptation finance, a higher focus on measuring, reporting and verification as well as on monitoring and evaluation of adaptation is likely to follow. Both will conceivable require clearer targets, indicators and metrics than presently available.

A global goal or target could be supplemented with sub-goals or targets that could be sufficiently flexible to be appropriate at regional, national, sector and lower level and allow for consideration of multiple dimensions and objectives. The Sustainable Development Goals (UN Open Working Group 2014) are relevant in this context (Box 2.2).

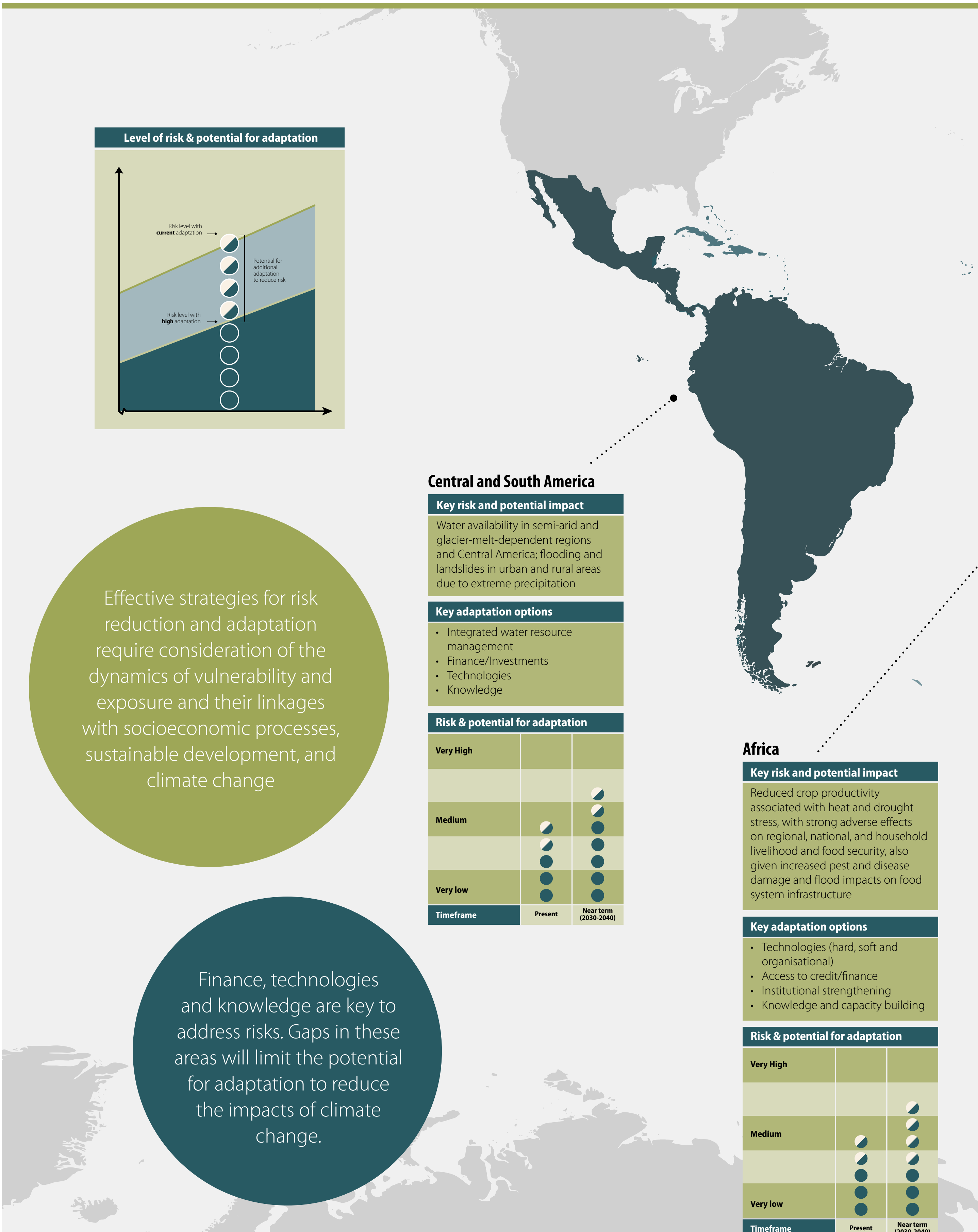
Box 2.2: The Sustainable Development Goals

One of the milestones of the Rio+20 United Nations Conference on Sustainable Development, held in June 2012, was the agreement by parties to launch a process to define a set of Sustainable Development Goals (SDGs). These would establish ambitious sustainability targets building upon the Millennium Development Goals and fostering the UN development agenda beyond 2015. With its outcome document, *The Future We Want*, Rio+20 instituted an intergovernmental Open Working Group (OWG) (UN Open Working Group 2014), entrusted with the task of delineating a proposal for these Goals and to present it at the 68th session of the General Assembly. On July 2014, the OWG submitted its outcome to the Assembly, containing a list of 17 Goals and 169 indicators that integrate economic, social and environmental aspects and recognize their linkages in achieving sustainable development in all its dimensions.

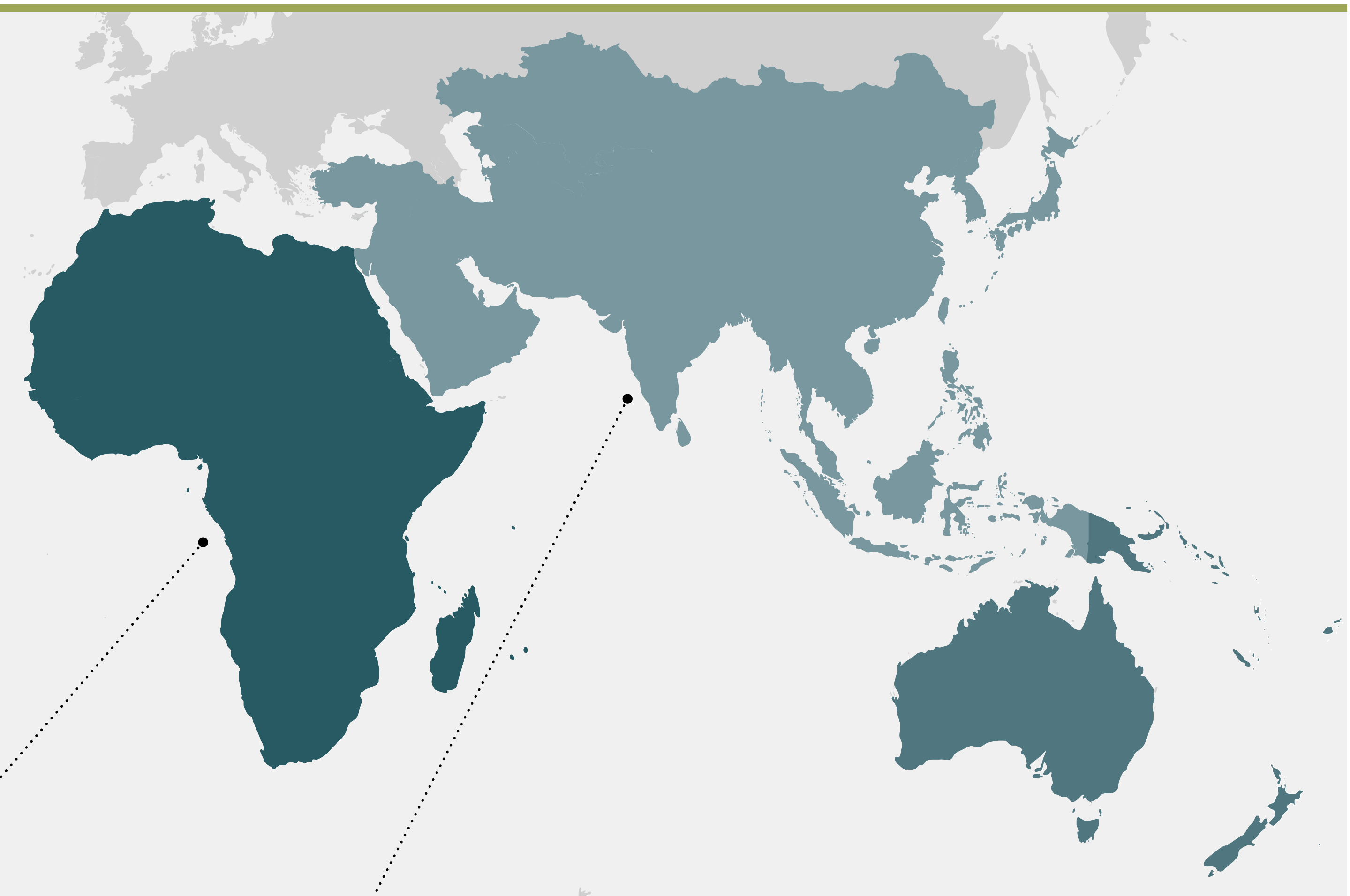
Climate change is considered in the SDGs both as a cross-cutting issue and as a stand-alone goal. Goal 13: Take urgent action to combat climate change and its impacts, is the main source of climate change action in the SDG proposal, and it is composed of targets on resilience, adaptation and disaster risk management, mainstreaming of climate change into national policies, capacity building and awareness-raising, as well as integrating climate financing under the UNFCCC framework.

These targets will be further developed through indicators focused on measurable outcomes. The identification of specific, quantifiable and climate-smart indicators against which to measure the progress made in achieving the SDGs will be crucial for its successful implementation and mainstreaming into national development agendas.

Figure 2.3: Examples of representative key risks for developing country regions and the potential for and limits to reducing them through adaptation now and in the near-term



Source: Authors' deliberation based on IPCC (2014d) Assessment Box SPM.2 Table 1



Asia (including West Asia)

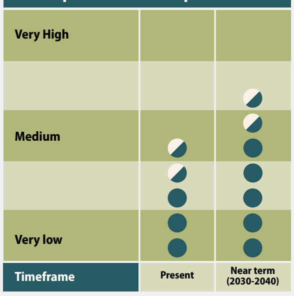
Key risk and potential impact

Increased risk of heat-related mortality

Key adaptation options

- Technologies
- Urban planning and development
- Knowledge and capacity building

Risk & potential for adaptation



Small Islands

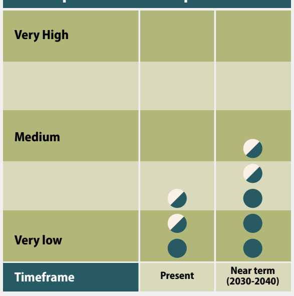
Key risk and potential impact

Loss of livelihoods, coastal settlements, infrastructure, ecosystem services, and economic stability

Key adaptation options

- Finance
- Technologies
- Maintain and enhance ecosystem functions and services

Risk & potential for adaptation



The Ocean

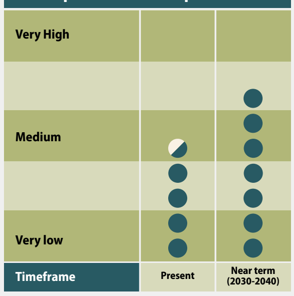
Key risk and potential impact

Reduced biodiversity, fisheries abundance, and coastal protection by coral reefs due to heat-induced mass coral bleaching and mortality increases, exacerbated by ocean acidification

Key adaptation options

- Reduce other stresses (enhance water quality; limit pressures from tourism and fishing)

Risk & potential for adaptation



Finally, an important motivation for adaptation efforts relate to the security of people, which means that setting adaptation targets is inherently related to social vulnerability. Frameworks that give weight to particularly vulnerable populations, such as low-income households, minorities, the elderly, women, children, etc., are therefore relevant. As early as 1990, Liverman (1990) argued for considering vulnerability in geographic space (where vulnerable people are) and vulnerability in social space (who in a place is vulnerable). Taking this approach further, Cutter *et al.* (2008a, 2008b, 2008c, 2003) argues for a geography of social vulnerability, that is the development of approaches that spatially determine most vulnerable people and those most at risk.

2.5.2 IDENTIFYING APPROPRIATE METRICS

A discussion of appropriate metrics must be seen in relation to adaptation targets. Currently there is little agreement on the most appropriate metrics of exposure, vulnerability, adaptation preparedness and impacts of climate change. There is a rich literature on adaptation metrics, but many are challenging as they are not measured consistently within countries let alone between countries; some respond too slowly to give any real measure of change, while others are subject to the vagaries of climate extremes and would take decades to show demonstrable (that is statistical) changes. Box 2.3 summarizes some specific approaches to measuring adaptation and progress on adaptation targets.

Box 2.3: Adaptation metrics: approaches and sources of information

The problems of measuring adaptation were recently assessed in the Fifth Assessment Report of the IPCC (Noble *et al.* 2014). The assessment describes the multiple expectations of measurements of adaptation, including identifying and understanding vulnerability; tracking progress in implementation, and in monitoring and evaluating the effectiveness of adaptation activities. It also describes the shift from a focus on biophysical measures such as estimating climate risks, exposure and potential impacts, to better understanding the capacity of households, communities, and institutions to cope with and reduce potential impacts (see for example Cutter *et al.* 2009).

Measures to identify adaptation gaps are more akin to those focusing on monitoring and evaluating outcomes of adaptation activities and the list below suggests some options with their strengths and weaknesses.

a) Direct measures of the impacts of climate related disasters on human populations—e.g. people killed, affected or financial losses (e.g. as in the Centre for Research on the Epidemiology of Disasters (CRED) database (CRED 2014)). Each of these three indicators conveys some information but there are problems in the quality of reporting and interpretation of the information. All have the problem that, within a country, disasters fortunately are relatively rare leading to a measure that is highly stochastic in time and place. For example, globally the number of people affected by climate related disasters varies 30 fold between the lowest (1985) and highest (2002) values since the mid 1970's (CRED 2014). Also, being based on disasters, such measures would largely miss the effects of less extreme but more frequent events (e.g. short droughts early in the growing season, heavy rains that damage crops and disrupt travel and communication) that can have significant cumulative effects on livelihoods.

b) Simple metrics equivalent to the Human Development Index (UNEP 2014b). The problem here is that a simple metric focuses on only a few indicators and is often strongly correlated with wealth (for example GDP per capita), and thus the metrics would convey little more information than is already available in many development indicators.

c) More complex metric based on multiple indicators. Here the indicators and methodology are difficult to agree upon; the resultant metrics that average many indicators tend to be slow and muted in their response; it is often difficult to get up-to-date data, and many composite metrics are strongly correlated with wealth even if wealth indicators are deliberately excluded. A number of multi-indicator metrics of vulnerability and capacity already exists (Brooks *et al.* 2011), but their results, even only in ranking countries, vary widely (Noble *et al.* 2014). If a multiple indicator approach was taken, the indicators should wherever possible be consistent with the new SDG indicators.

d) A small basket of metrics or indicators that cover specific aspects of the adaptation gap. These can include financial metrics, measures of risk; measures of capacity, etc. Thus the adaptation gap is acknowledged and treated as multidimensional.

e) A checklist approach, similar to the Hyogo Framework for Action score (UNISDR 2011) where a number of steps and achievements in developing responses to climate risk are identified. The number of items yet to be achieved could be used as a simple indicator of adaptation gaps.

f) A monetary metric at the global level that could be supplemented by measuring gaps at regional and local levels using a wider range of measures. However, as described in Chambwera *et al.* (2014) and in Chapter 3 of this report, estimates of the costs of adaptation are subject to considerable methodological differences and differences in the sectors included. Chapter 3 describes the use of Integrated Assessment Models (IAMs) to try to achieve this in a more comprehensive way. The interpretation of what constitutes expenditure on adaptation is difficult, with many local expenditures not being captured and the distinction between adaptation and development expenditures remaining difficult.

2.6 SUMMARY

There are many ways to define an adaptation gap. This chapter suggested a generic definition for the adaptation gap as the difference (shortfall) between actually implemented adaptation and a societally set goal, determined largely by preferences related to tolerated climate change impacts reflecting resource limitations and competing priorities. While frameworks can be visualized, a major challenge is to find suitable ways of measuring the adaptation gap so that progress towards reducing that gap can be monitored. Different societies and groups within a society will vary in their preferences about both the goal and the means of measuring progress towards it. This will make the measurement of a global adaptation gap challenging.

The final choice of definition of the adaptation gap or gaps, and the metrics used to track changes in the gap(s) will depend on the purpose that the climate change community seeks for such a measure. The climate negotiations have tended to focus on financial gaps as the provision of finance for adaptation in developing countries is core to current negotiations under the UNFCCC. But finance is a means not an end. If the identification of gaps is to be used to assist countries and development agencies to focus efforts in tackling adaptation, a monetary metric in combination with other metrics or metrics based on a wider range of indicators will be more informative.

The adaptation gap can also be looked at through more specific lenses. This is the approach of the following chapters which, in Chapter 3, assess whether current levels of adaptation finance are on a trajectory towards achieving an adaptation target and whether a potential adaptation funding gap exists. Chapter 4 examines whether there is a real or perceived gap in the availability of the technology needed, in particular, by developing countries, while chapter 5 discusses whether a knowledge gap exists and how it can be bridged by addressing lack of knowledge, failures to link different bodies of knowledge, and limits to the diffusion of knowledge.

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03

CHAPTER 3

THE ADAPTATION FUNDING GAP

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3.1 FRAMING THE ADAPTATION FUNDING GAP

In this chapter we investigate the economic and financial aspects of the adaptation gap to analyse the potential adaptation funding gap in the future. These issues are particularly relevant in relation to the finance pillar of the UNFCCC and the Green Climate Fund. The Green Climate Fund is expected to significantly contribute towards addressing adaptation needs in developing countries, aiming as it will for a balanced (50:50) allocation of its resources between mitigation and adaptation (GCF 2014).

As illustrated in Chapter 2, the adaptation gap is not a scientifically defined quantity. It depends on the goals and targets set for adaptation, which can involve various framings and objectives depending on actors (private and public) and scale (from local to global). It can also involve different levels of trade-off between the costs and benefits of adaptation and the residual risks after adaptation. Finally, consideration of the future adaptation gap involves complex ethical as well as scientific issues.

In broad terms, the adaptation funding gap can be defined as the difference—now and in the future—between adaptation needs measured in terms of costs, and the amount of finance available. An important dimension of the adaptation funding gap is that it is emissions dependent. The emissions dependency can be explored by comparing adaptation needs in a high-emission pathway with adaptation needs in a low-emission pathway.

As the chapter shows, both of these approaches involve major challenges in terms of estimation. It is difficult to assess future needs, especially in aggregate terms; these are often subjective in nature. It is also difficult to relate future needs to current finance as the time-scales and even the metrics are not directly comparable. Furthermore, the future impacts of climate change arise against a background of current climate variability and extremes that most countries and communities are not fully resilient to. This current adaptation gap is not primarily caused by anthropogenic climate change but is part of the broader challenge of integrating adaptation in climate resilient development. However, adaptation to future climate change will be less effective if current gaps have not first been addressed (Burton 2004). This raises issues around what actions fall into the development gap and what into the adaptation gap (see Box 2.1). Taken together, these various issues make it very difficult—indeed impossible—to provide a definitive cost of adaptation, and in turn to accurately estimate the adaptation funding gap.
However, it is still informative to look at the available evidence on needs and finance and provide indicative findings on the potential future adaptation funding gap and how it can be bridged. This is the aim of this chapter.

The chapter first reviews the available evidence of future adaptation needs. This focuses on estimates of the costs of adaptation and residual risks in order to provide aggregated indicators. The review starts with the available global estimates; it then compares these to a review of national and sector studies. It also reviews methodological approaches and coverage of these studies. This is followed by an overview of current public adaptation finance flows. The final section summarizes indicative findings on the adaptation funding gap, as well as potential options to bridge it.

3.2 ESTIMATES OF THE COSTS OF ADAPTATION

Over the past few years, there have been a number of reviews of the costs and benefits of adaptation (Agrawala *et al.* 2011, UNFCCC 2010a, Watkiss and Hunt 2010, OECD 2008, EEA 2007). These report a low evidence base and find that estimates differ with the scenario of climate change; the methods used, the objectives adopted, the assumptions made; the spatial, sector, and temporal contexts; and whether residual impacts and uncertainty have been included.

However, over recent years there has been a growing literature on the costs and benefits of adaptation that can be used to explore estimates of potential future adaptation needs, including global, national and local studies.

Table 3.1 provides an overview of key global and national studies in this area. Referring to Chapter 2, the objectives adopted by available studies can be interpreted as adaptation targets, or 'societally desirable adaptation'. As Table 3.1 shows, these range from maintaining levels of welfare at pre-climate change levels (EACC studies), to economic efficiency (IAM modelling), to needs-based and country-specific targets (UNFCCC and UNDP studies). In this way they represent assessment of very different adaptation gaps as discussed in Chapter 2. In principle, the estimates in the table would be expected to reflect these different implicit adaptation targets. As the table illustrates, however, other aspects including sector and spatial coverage and methods

Table 3.1: Overview of studies of costs and benefits of adaptation, their assumptions, methods and estimates

Study	Aggregation	Method	Objective/ implicit adaptation target	Strengths	Issues	Cost estimates
UNFCCC IFF (UNFCCC 2007) UNFCCC IFF update (UNFCCC 2008)	Global	Global Investment and financial flows	Analysis/ Needs based	Grounded in current finance flows	Partial coverage. Little consideration of uncertainty	US$30 to US$70 billion/year (developing countries) and US$50 to US$170 billion/year (globally) by 2030 (2007). Estimates in range of tens of billions of United States dollars in 2030, possibly hundreds of billions (2008)
Integrated Assessments (for example, de Bruin 2014)	Global	Global Economic Integrated assessment Modelling	Economic efficiency	Explicit link from climate damage to adaptation cost/ benefit	Partial coverage, exclusion of uncertainty and policy costs	Increasing from US$19 to US$429 billion/year for the period 2010–2050 under a 2°C scenario
World Bank EACC (World Bank 2010a)	Global	Sector impact assessment	To maintain levels of welfare at pre-climate change levels	Explicit link from climate damage to adaptation cost/benefit. Consideration of climate uncertainty	Partial coverage, if-then framework, exclusion of policy costs, assumption of 2°C change	US$70 billion to US$100 billion a year, increasing from US$60 to US$70 billion for the period 2010–2019 up to US$90 to US$100 billion by 2040–2049
World bank EACC (World Bank 2010a, 2010b and 2010c) – country studies	National (seven countries)	Sector impact assessment plus macro-economic and social analysis	To maintain levels of welfare at pre-climate change levels	As above, but greater detail, inclusion of cross-sector and wider economic effects	As above	Examples: Ethiopia: US$1.2 billion to US$5.8 billion per year (2010–2050) Mozambique: US$0.3 to US$0.8 billion per year by the 2030s to address sea level rise
UNDP IFF (UNDP 2011)	National (15 countries)	Sector Investment and Financial Flow Analysis	Analysis/ Needs based	Grounded in current flows, high sector detail, and coverage, include policy costs	Adaptation objectives not necessarily defined, often elements of adaptation deficit included. Uncertainty not well covered	Total estimate US$5.5 billion/year in 2020 rising to US$7.1 billion/year in 2030 for 1-2 sectors in each of 15 countries
UNFCCC NEEDS (UNFCCC 2010a)	National (five country adaptation studies)	Varied	Country specific	Varied	Varied	Cumulative short- and long-term costs of adaptation measures range from USD 161.5 million to USD 20.69 billion per country

Source: ECONADAPT Project (Watkiss et al. 2014). Values reported as original study values and $/year.

and time scale considered seem to have larger implications for the estimates than the implicit adaptation target.

In the following, we provide further detail on the global studies and review a range of national and sector studies.

3.2.1. GLOBAL ESTIMATES

At the global level, the IPCC 5th Assessment Report (Chambwera *et al.* 2014) reported that the most recent global adaptation cost studies suggest a range of US$70 billion to US$100 billion per year globally by 2050 for developing countries, but highlights the fact that there is little confidence in these numbers. This estimate is primarily based on the EACC (World Bank 2010a) study in Table 3.1, which is slightly higher than the UNFCCC (2007) study for similar regions. The EACC estimate is a very low percentage (0.17 per cent) of the current income of the countries assessed, and will be an even lower proportion in future years with development. For the countries considered it equates to just over US$10 per person per year in 2050. In comparison, the UNFCCC (2007) study estimates the potential increase in global investment needs for adaptation corresponds to 0.06–0.2 per cent of projected global GDP by 2030 (that is for all countries). The breakdown by region and sector is shown in Table 3.2.

A critique by Parry and others (Parry *et al*. 2009) of the earlier (2007) UNFCCC global cost estimates concluded these underestimated adaptation costs by a factor of 2 to 3 for the sectors considered. This finding also applies to the EACC estimates (World Bank 2010a), that is the coverage of impacts and sectors are partial, and furthermore, adaptation costs are calculated as though decision-makers know the future with certainty.

The EACC (2010a) estimate assumes that the world will embark on an emission pathway that will limit global warming to 2°C which is the current long-term global goal identified under the UNFCCC process. As illustrated in the Emissions Gap Report (UNEP 2013a), the world is currently on an emission trajectory that corresponds to global warming in the range of 3.7°C. To highlight the emissions-dependency of adaptation needs, new runs with the global economic integrated assessment AD-RICE model have been undertaken for this report (de Bruin 2014) with details provided in Annex A (available online). This provides useful insights on how impacts and adaptation costs could vary along different emission pathways. Figure 3.1 presents adaptation costs as a percentage of regional GDP for developing countries for a 2°C (dotted line) and a 4°C world scenario (black line). Uncertainty ranges are included around the median estimates in the figure (shaded areas), representing the 16th–84th percentile range. The figure shows that adaptation costs rise steeply over time in the higher emission scenario and could be around twice as high in the 4°C world scenario than they are in the 2°C scenario by 2050[1]. The indicative results support the message that immediate and strong mitigation action is the best insurance against an unmanageable adaptation gap.

These economic integrated assessment models have also been applied at the continental level, including in the Africa's Adaptation Gap Report (UNEP 2013b) and the ADB study (2014) on the Economics of Climate Change for South Asia. These regional studies tend to indicate higher adaptation costs than the global EACC (World Bank 2010a) and UNFCCC

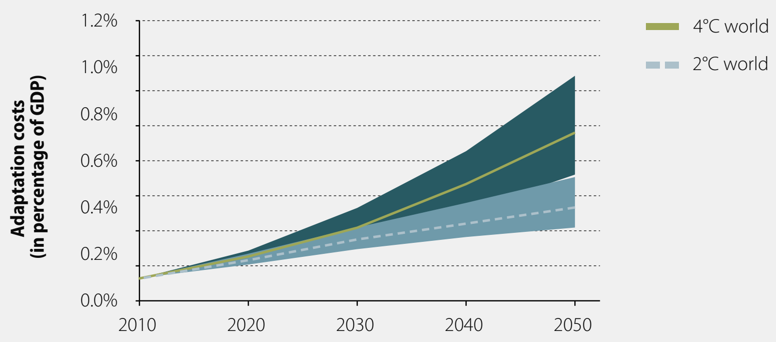
1 The adaptation costs in the 2°C and 4°C scenarios diverge early in the AD-RICE model for two main reasons: the AD-RICE model estimates for adaptation are based on the RICE model costs of impacts, which perform a quadratic function of impacts. Therefore, the costs of adaptation follow a similar quadratic increase, which is a function of the temperature level used as input in both models; the AD-RICE model estimates the costs of adaptation for both proactive (anticipatory) and reactive adaptation. Proactive adaptation costs are modelled as an investment in an adaptation capital stock, which will decrease future damages. As anticipated adaptation needs in a 4°C scenario after 2040 are significantly higher than in a 2°C scenario, investments are increased in the short run in the 4°C scenario. Since investments in adaptation decrease consumption in the investment period, anticipatory adaptation costs will be spread over periods (despite 5 per cent adaptation capital depreciation) enhancing adaptation investments in the short run. This is due to so-called consumption smoothing.

Table 3.2: Adaptation cost estimates for developing country regions and sectors (over period 2010 – 2050, dry X sum scenario, 2005 US$ billions, no discounting)

Region	US$ Billion	Sector	US$ Billion
East Asia & Pacific	17.9	Infrastructure	13.0
Central Asia	6.9	Coastal zones	27.6
Latin America & Caribbean	14.8	Water supply and flood protection	19.7
Middle East/ North Africa	2.5	Agriculture, forestry, fisheries	3.0
South Asia	15.0	Human health	1.5
Sub-Saharan Africa	14.1	Extreme weather events	6.4
Total	**71.2**	**Total**	**71.2**

Source: World Bank (2010a)
Note: X-sums net positive and negative items within countries but not across countries

Figure 3.1: Adaptation cost estimates as a percentage of GDP for developing countries in a 2°C (IPCC RCP2.6) and 4°C world (IPCC RCP8.5) between 2010 and 2050. Included 16th-84th percentile range (shaded area)



Source: AD-RICE2012 model

(2007) studies. As an example, the annual average adaptation costs (for 2010–2050) in South Asia (Bangladesh, Bhutan, India, Maldives, Nepal, and Sri Lanka) were estimated at US$30 billion to US$40 billion/year for the region.

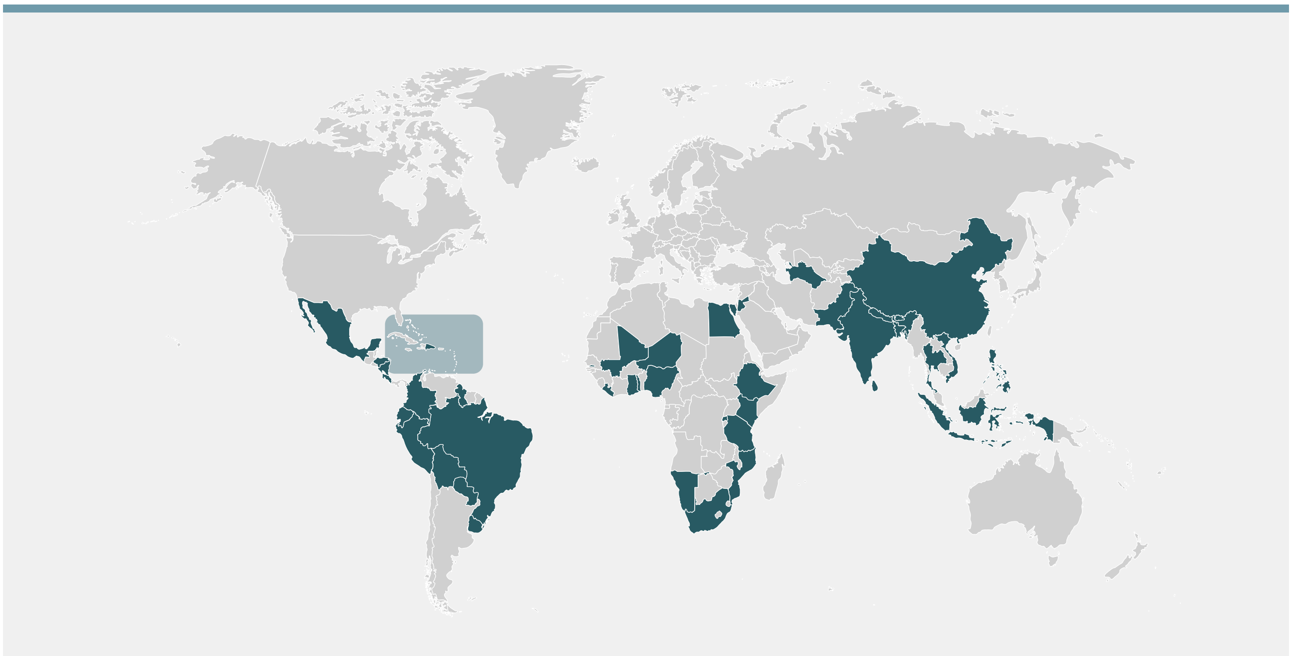
3.2.2 NATIONAL AND SECTOR ESTIMATES

NATIONAL STUDIES

In recent years, a number of country level initiatives have emerged that provide estimates of the costs of adaptation. These include the UNDP Assessment of Investment and Financial Flows (IFF) to Address Climate Change (UNDP 2011), the World Bank EACC country studies (World Bank 2010a), the UNFCCC National Economic, Environment and Development Study (NEEDS) (UNFCCC 2010a), the Regional Economics of Climate Change Studies (RECCS): (Pye *et al.* 2010), and individual country or sector initiatives. A mapping of these studies (Watkiss *et al.* 2014, as part of the European Union Seventh Framework Programme funded ECONADAPT project) has identified that around 50 developing country studies have been considered through these assessments, with coverage presented in Figure 3.2[2]. These provide complementary evidence to the global estimates above on the possible costs of adaptation.

2 This section was compiled by the ECONADAPT project team based on research undertaken in the project. The ECONADAPT project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No 603906.

Figure 3.2: Coverage of regional and national studies for developing countries



Source: ECONADAPT (Watkiss et. al. 2014)

The seven World Bank EACC country studies (World Bank 2010a) in Bangladesh, Bolivia, Ethiopia, Ghana, Mozambique, Samoa, and Vietnam complement the global EACC estimate cited above, and used the same impact-assessment framework. The studies provide a more detailed (bottom-up) assessment, and allow the analysis of economy wide effects. Some countries and sectors showed a relatively close agreement between global and local estimates, with local costs around 10-20 per cent higher due to the consideration of cross-sector and socially contingent effects. A number of the country studies, however, indicated very much higher costs than the global analysis. For example, the country study in Ethiopia (World Bank 2010b) estimated the costs of adaptation and the residual impacts together for this one country alone could be US$1.2 billion to US$5.8 billion per year (2010–2050). Similarly, the costs for Mozambique for addressing sea level rise (World Bank 2010c) were estimated at US$0.3 billion to US$0.8 billion per year by the 2030s.

An alternative set of country adaptation costs was produced under the UNDP's IFF initiative, which used a different method centred on investment and financial flows. These studies estimate the additional adaptation costs required through to 2030. A total of 15 country studies were undertaken Bangladesh, Colombia, Costa Rica, Dominican Republic, Ecuador, Gambia, Honduras, Liberia, Namibia, Niger, Paraguay, Peru, Togo, Turkmenistan, and Uruguay, focusing on one or two key sectors each, primarily agriculture and/or water. The total additional adaptation needs across all 15 countries (for the one/two sectors covered in each case) was estimated at US$5.5 billion/year in 2020, and rising to US$7.1 billion/year in 2030.

These are much larger costs than estimated by the EACC study in terms of individual country estimates and, by implication, the global total. For example, the adaptation costs in the 12 UNDP IFF country assessments of agriculture totalled US$3 billion/year in 2020 rising to US$6 billion/year in 2030. This is actually higher than the estimated global costs of adaptation for agriculture reported by the EACC study (Table 3.2)—even though the latter includes all developing countries.

This implies a major difference between the two sets of estimates that can be explained partly by the different methods, assumptions and coverage. The IFF studies are better grounded in current policy and include much greater coverage of risks as they look towards building resilience across all existing policy areas. They have a more realistic assessment of the costs of delivering adaptation— including implementation and policy costs—and costs to the private as well as the public sector. However, they include some costs for actions that are targeted at reducing the existing adaptation and development deficits (see Box 2.1).

A further study—the UNFCCC NEEDS (UNFCCC 2010a) -assessed mitigation and adaptation needs in ten countries, of which Egypt, Ghana, Maldives, Mali, and Nigeria estimated adaptation financing needs. The estimated short- and long-term costs of adaptation measures as reported by the countries range from US$161.5 million to US$20.69 billion, though the countries used different methodologies and approaches, over different time-scales.

Finally, a number of other regional and country level initiatives have provided estimates—including in Bangladesh, Brazil, Bhutan, Caribbean, Central America, China, Egypt, Ethiopia, Kenya, Guyana, India, Indonesia, Maldives, Mali, Nepal, Philippines, Rwanda, Samoa, South Africa, Sri Lanka, Tanzania, Thailand, and Vietnam. While the different methods make direct comparison difficult, these estimates generally indicate higher adaptation costs than the global EACC study.

SECTOR STUDIES

Aside from national initiatives, there are growing numbers of sector specific and risk focused studies, often at the local level. A compilation of these (Watkiss *et al.* 2014) as part of the European Union (EU) Seventh Framework Programme funded ECONADAPT project has identified several hundred studies. Analysis of these provides some additional evidence and insights into the possible costs of adaptation (Watkiss *et al.* 2014).

The most comprehensive information on the costs of adaptation is for coastal zones and the risks of rising sea levels and storm surges. There is now sufficient evidence to examine how costs cascade from the global to national to local levels, as well as to consider lessons from more practically based assessments. At the global level, there is information on the potential costs of adaptation in terms of protecting coastlines with dykes and using beach nourishment to reduce coastal erosion (Hinkel *et al.* 2014, Hinkel *et al.* 2013). These indicate that annual investment and maintenance costs are potentially large, estimated at US$12–31 billion/year under RCP2.6 (2°C) and US$27–71 billion/year under RCP8.5 (by 2100). This value is similar to the sector cost estimate of the EACC study (World Bank 2010a) as illustrated in Table 3.2. However, analysis of national and local estimates, which allows for more detailed assessment, suggests these values are conservative. This is because global studies do not consider building uncertainty into options: they assume existing and good levels of protection; they focus on technical options and costs; and they optimise towards relatively modest levels of risk reduction. More detailed national and especially localized studies allow some consideration of the impact of considering these aspects and the costs of moving towards adaptation implementation. Such studies generally reveal much higher costs of adaptation, particularly for major coastal cities and ports. As an example, the estimated annual costs for future flood protection/risk management in the Netherlands alone have been estimated at more than US$1.25 billion per year (that is € 1 billion, Delta Commissie 2008). Similarly, the costs of an additional barrier and supporting works for London to address rising sea levels, which will potentially be needed later this century, has been estimated at US$9.5 to US$11.1 billion (that is £6 to £7 billion, EA 2009, 2011).

At the other extreme, estimates of the potential impact of climate change and the cost of adaptation are almost completely missing for biodiversity and ecosystem services; they are therefore not included in the global estimates above. This is a major omission as these are among the most vulnerable of all sectors because of ecological limits and low adaptive capacity. The limited studies that do exist (Parry 2010) indicate sector costs could be much larger than estimates for quantified sectors.

A similar issue exists on risk coverage: many of the earlier studies of climate change impacts, and thus adaptation costs, are focused on temperature increases and slow-onset change, but there are potentially more important risks arising from changes in the frequency and intensity of extreme weather and climate events ('climate related natural hazards'). These are recognized in the IPCC SREX report (2012). The probable and highly site-specific nature of these events makes them more difficult to include in an aggregate framework, but they are likely to be a major factor in early damage costs and thus a priority for early adaptation, as identified increasingly in the national studies discussed above.

3.2.3 DISCUSSION OF ESTIMATES

As discussed in the sections above, the analysis of national and sector studies strongly indicates that the current reported global value from the EACC study (US$70 billion to US$100 billion per year globally by 2050 (World Bank 2010a)) is likely to be a significant underestimate, particularly in the period 2030 and beyond. There are a number of reasons for this:

Firstly, the coverage of the global estimates is partial and only includes a limited number of sectors and impacts from climate change. This alone is likely to mean the current global value underestimates costs significantly. The current estimate also aggregates losses and gains when in practice such transfers will not be possible. Agricultural productivity gains, for instance, cannot easily be transferred into adaptation finance for health.

Secondly, estimates such as the global EACC study are based on funding adaptation for 2°C of climate change, when studies indicate that we are currently on a 3.7°C pathway (UNEP 2013a). As highlighted by the integrated assessment modelling analysis in this chapter, higher rates of warming could lead to significant increases in global economic damages and adaptation costs, even in the medium-term: indeed the AD-RICE model runs indicate the costs of adaptation could approximately double by 2050 under a high emission pathway. This is mainly due to the need for earlier and greater anticipatory action. Furthermore, in practice, higher costs are likely on higher emission pathways due to the speed of climate change, and the ability of natural, physical and economic sectors to adapt, as well as the limits of adaptation. These differences will be magnified in later years for higher warming.

Thirdly, uncertainty around future climate change also increases costs as it requires different responses to a predict–then–optimize framework where the future change is known, as assumed in many current global estimates. These additional costs can be reduced through iterative climate risk management and decision making under uncertainty, but this requires higher adaptive capacity, which in turn has a cost. Similarly, more practically focused studies indicate that cost categories are being ignored in the current estimates and that costs are likely to be higher in practice.

Finally, as adaptation moves from theory to practice, a greater understanding is emerging of the challenges with its implementation and the effects on costs (Watkiss *et. al.* 2014). This raises both positive and negative issues: there is a potential for non-technical adaptation (capacity building and soft measures) that will have lower costs than engineering based options (Agrawala *et al.* 2011), including "low regret" or "no regret" options that may offer large co-benefits. It is also likely that economies of scale, enhanced private sector involvement, innovation and learning will reduce costs further. Against this, however, many current technical options and cost estimates are likely to be more expensive in practice: a lesson that has already emerged in the mitigation domain where negative cost options are rarely easy or as cheap to implement as estimated owing to a range of barriers. Similarly, for adaptation, the technical costs of many options, as used in the current global estimates, are likely to be underestimates because of various opportunity, transaction and policy costs. Examples of this include the high opportunity costs from labour and land or up-front cash outlays for climate smart agriculture (McCarthy *et al.* 2011); high land acquisition/opportunity costs of set-back zones in coastal areas (Cartwright *et al.* 2013); the increasing resource costs of heat alert systems as these are triggered more frequently with climate change (Hunt and Watkiss 2010), or the rising costs of irrigation due to greater competition for water. It is also apparent that the effectiveness of adaptation assumed in the current studies is high and that implementation occurs within an effective governance and implementation framework when, in practice, the implementation of such options in developing countries, and in Least Developed Countries (LDCs) in particular, is likely to be significantly lower due to development challenges.

In summary, there is no definitive answer to the question of how large the sum of adaptation cost/residual damages might be. National estimates in the sections above indicate a potential profile of costs that start at a similar order of magnitude to the EACC values in 2020 (that is US$50 billion) for developing countries, but rises rapidly by 2030 and increases much faster in subsequent decades than indicated by the EACC numbers. Under higher emission trajectories, the profile of costs post 2030 is even higher.

Taking the various lines of evidence into account, it would seem plausible that the indicative cost of adaptation and the residual damage for the LDCs alone is likely to be in the range cited by the EACC study—that is, US$50 billion/year by 2025/2030 and possibly double this value (US$100 billion/year) by 2050. Extending the analysis to all developing countries, the information above could imply plausible costs of US$150 billion/year by 2025/2030 and US$250 billion to US$500 billion/year by 2050. These estimates are largely based on climate change estimates where warming is limited to 2°C above pre-industrial levels. In cases of higher warming pathways, post 2030 cost of adaptation/residual damages are likely to rise very significantly due the higher levels and rate of change and the greater level of anticipatory adaptation. While the evidence is very limited, the IAM runs undertaken indicate that a 4°C pathway could potential double adaptation cost/residual damage by 2050.

3.3 CURRENT ADAPTATION FINANCE FLOWS

In this section, we provide an overview of the current levels of finance targeting climate change adaptation based on the latest available data with the main focus on public flows. The limited availability of data prevents the inclusion of private finance flows; there are also considerable challenges related to estimates on domestic spending. Both of these would help establish a more comprehensive overview of current adaptation finance flows.

We cannot directly relate future adaptation needs in terms of costs as in the previous section with the current levels of public finance flows. However, information on current levels of finance flows gives an indication of how these compare to the levels likely to be needed in the future.

Although public finance flows are likely to play a major role in bridging adaptation funding gaps in developing countries, private finance is an essential complement. A discussion about the share of the adaptation funding gap that could or should be covered by public finance flows is beyond the scope of this report and involves complex normative, ethical, distributional and scientific issues.

It is equally important to note that measuring the *quality* as well as the *quantity* of adaptation-related funding is crucial. Achieving better results for the world's poor using public funds requires assessing *how* adaptation finance is being accessed, managed, used and delivered. There is increasing interest in assessing the effectiveness of climate finance, as evidenced by a rapidly growing body of research (Nakhooda *et al.* 2014, Ellis *et al.* 2013, Nakhooda 2013, Buchner *et al.* 2012a).

Notwithstanding the importance of these issues, the following section is limited to estimating public commitments[3] for adaptation-related finance made in 2012/2013, supplemented with information about trends over time. This in itself involves a number of conceptual and methodological challenges, including the lack of an internationally agreed definition of what qualifies as adaptation finance or, more narrowly, of what qualifies as an adaptation intervention.

Although consensus on methodologies for tracking, measuring and reporting still remain to be established, there are more similarities than differences in them (OECD 2013). There is also progress in the development and use of harmonized approaches (see for example, AfDB *et al.* 2013 and AfDB *et al.* 2012, and the definition of climate adaptation-related aid put forward by the Development Assistance Committee (DAC) of the Organisation for Economic Co-operation and Development (OECD)).[4]

3.3.1 ESTIMATES OF PUBLIC ADAPTATION FINANCE

The overview of public adaptation finance flows in this section is based on data from the main providers of public adaptation finance. These are:

- Development Finance Institutions (DFIs), including Bilateral, Multilateral, and National DFIs;
- Governments, through bilateral Official Development Assistance (ODA) contributions, and
- Climate Funds targeting adaptation operating through national, regional or multilateral organizations.

With the exception of national Development Finance Institutions that raise and channel finance for adaptation investments (aimed at achieving domestic adaptation goals), the other entities grant or invest their resources with the aim of providing financial and technical support to developing countries and emerging economies, and/or coordinate support among their member countries.

3 See online Annex A for details on definitions and the methodology used.

4 For recent developments see for example OECD (2014a) and http://www.oecd.org/dac/environment-development/joint-tt-march-2014.htm.

It should be noted that a complex interplay exists between these actors. Governments can, for instance, pool their non-refundable or highly concessional resources in Climate Funds, or put them towards supporting the ability of Development Finance Institutions to develop and finance a wide range of climate-resilient activities on preferable terms. Concessional funds from donor and Climate Funds can in fact be "blended" alongside multilateral ones belonging to DFIs to achieve the level of concessionality required by the additional costs and risk premium of adaptation projects, or to compensate for the real or perceived higher risks of pilot and demonstration projects.

PUBLIC ADAPTATION-RELATED FINANCE FLOWS

Public adaptation-related finance (excluding domestic budgets) is estimated at US$24.6 billion (range: US$23–26 billion) in 2012/2013 (Buchner *et al.* 2014). Out of this total, about 90 per cent or US$22.2 billion was invested in developing countries, under which we include all non-Organisation for Economic Co-operation and Development (OECD) countries as well as Chile and Mexico (Buchner *et al.* 2014).

These figures are a combination of ODA and non-ODA (Other Official Flows)[5] finance originating from developed and developing country governments, adaptation dedicated Multilateral Climate Funds and DFIs.

These flows are broader than international climate finance as reported under the UNFCCC against Fast-start Finance commitments to provide "new and additional" resources approaching US$30 billion for the period 2010–2012 and should not be confused with the amount that counts towards developed countries goal of mobilizing jointly US$100 billion per year by 2020 (for both mitigation and adaptation).

It is important to note that it is unclear how much of the adaptation finance reported in this section is "new and additional" given the lack of agreed definition of the terms "new" and "additional" and accounting methods. Past research on public climate finance contributions during the Fast-start Finance period raised questions about whether finance was "additional" to targets to deliver 0.7 per cent of Gross National Income as ODA (Oxfam 2012). Only a small share of Fast-start Finance was generated from new (non-ODA) sources and several contributions reflected pledges made prior to the Fast-start Finance period, as well as long-standing climate-relevant programs (Nakhooda *et al.* 2013). Climate-related spending (including through ODA) did increase substantially during the Fast-start Finance period, and at a faster rate than ODA as a whole. However, recent survey findings have shown that many OECD DAC members only report a share of climate-related ODA towards their UNFCCC commitments (Gaveau and Ockenden 2014).

Figure 3.3 provides an overview of estimated public adaptation finance commitments in 2012/2013 by source, instrument, sectoral use, and target region.
As Figure 3.3 shows, DFIs intermediated and channelled US$21.7 billion or 88 per cent of total public finance invested in activities targeting adaptation objectives, about half of which was channelled by national DFIs and deployed mostly domestically[7]. Other governmental channels financed 9 per cent, while adaptation dedicated Climate Funds financed the remaining 2 per cent. These finance providers also contributed US$4 billion for projects with both mitigation and adaptation objectives. In the following sections we take a closer look at sources and intermediaries of public adaptation finance, as well as sector and regional prioritization.

DEVELOPMENT FINANCE INSTITUTIONS

DFIs have been the dominant public source of adaptation finance in developing countries over the last years (Buchner *et al.* 2014, 2013, 2012b and 2011). In 2013, multilateral DFIs, such as the World Bank, delivered about 34 per cent of total DFI adaptation commitments, or US$7.4 billion; and bilateral DFIs, contributed 15 per cent or US$3.2 billion. National DFIs contributed the remaining 51 per cent or US$11.2 billion.[8] The China Development Bank contributed a substantial share of this total (Buchner *et al.* 2014). Adaptation finance commitments by DFIs increased by US$4 billion since last year (Buchner *et al*. 2014).

BILATERAL ODA FLOWS

Bilateral adaptation-related aid commitments by members of the OECD DAC indicate that adaptation is increasingly mainstreamed within development cooperation activities. Adaptation represents around 43 per cent of total climate

5 To qualify as ODA, financial assistance has to have a grant element of at least 25 per cent (calculated at a rate of discount of 10 per cent) see (OECD 2008). Funds that do not include a sufficient grant element to qualify as development assistance are the so-called Other Official Flows (OOF).

6 Note: Figures may not add up to the total because of rounding. Where ranges of estimates are available, the mid-point is presented.

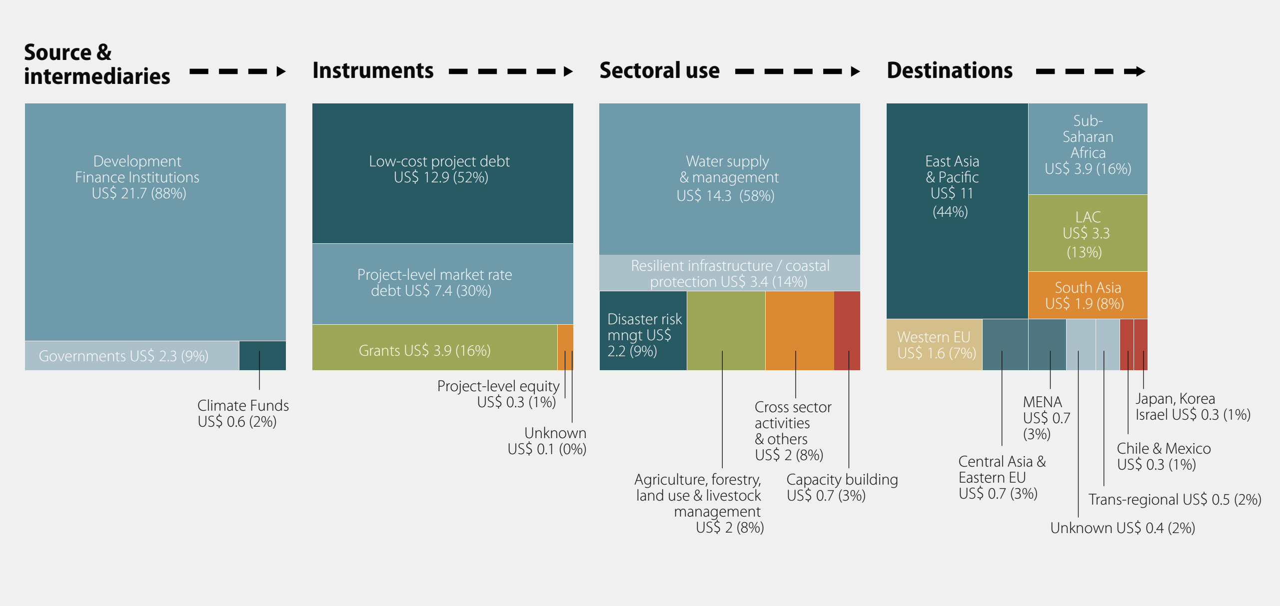
7 Global estimates aggregate data qualifying as adaptation according to the definition of the OECD DAC Rio marker on climate change adaptation-related aid and the "process-based" approach developed jointly by a group of Multilateral Development Banks (see AfDB *et al.* 2012 and 2013). The approach followed by the International Development Finance Club (Ecofys & IDFC 2012, 2013) was also considered. To compile this data Buchner *et al.* (2014) used three major sources of information: 1) The OECD DAC Creditor Reporting System database; 2) studies compiled by other organizations (see Ecofys & IDFC 2014; ODI/HBF 2014); 3) and self-reporting of primary project-level data by five Multilateral DFIs; 4), an ad-hoc financial survey.

It should be noted that the data compiled are not fully comparable because various organizations of the *Landscape* use different tracking methodologies (see Buchner *et al.* 2014 for further details).

The risk of double counting was minimized by the use of project-level data and scrutiny of aggregated flows.

8 The group of National DFIs includes, inter alia, the China Development Bank, the Brazilian Development Bank, the Mexican Development Bank . See Buchner *et al.* (2014) for details.

Figure 3.3: Breakdown of 2012/2013 public adaptation finance commitments, in US$ billion at current prices and percentage of total



Source: CPI author's elaboration based on Buchner et al. (2014)

Figures may not add up to the total because of rounding. Where ranges of estimates are available, the mid-point is presented

aid[9] and is mainly provided by Japan, Germany and EU Institutions (OECD 2014b). The majority is committed through grants and almost 20 per cent is directed to specific Funds and programmes (OECD 2014b). See Annex A for further information on OECD DAC bilateral adaptation-related aid commitments.

ADAPTATION DEDICATED CLIMATE FUNDS

In 2013, and as shown in Figure 3.3, adaptation dedicated Climate Funds committed US$0.6 billion to developing countries, about 2 per cent of total adaptation finance (Buchner *et al.* 2014, mainly based on the Climate Funds Update (ODI/HBF 2014)).[10]

The operation of the Financial Mechanism of the UNFCCC is entrusted to two operating entities: The Global Environment Facility (GEF) and the Green Climate Fund (GCF). The GEF manages two adaptation-relevant funds: the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF). The GCF was established in Cancun at COP 16 (UNFCCC 2010b) and will aim for a balanced (50:50) allocation of its resources between mitigation and adaptation over time (GCF 2014). It is intended to be the main fund for global climate change finance in the context of mobilizing US$100 billion by 2020. The Adaptation Fund operates under the Kyoto Protocol. It is managed by the Adaptation Fund Board, with the interim secretariat being the GEF secretariat and the interim Trustee being the World Bank. Outside the UNFCCC is the Pilot Program Climate Resilience—an adaptation targeted program of the Climate Investment Funds— and the Global Climate Change Alliance of the EU, which also supports mitigation activities. National Climate Funds supporting adaptation measures include the Bangladesh Climate Change Resilience Fund (BCCRF), Bangladesh Climate Change Trust Fund (BCCT), and Indonesia Climate Change Trust Fund (ICCTF).

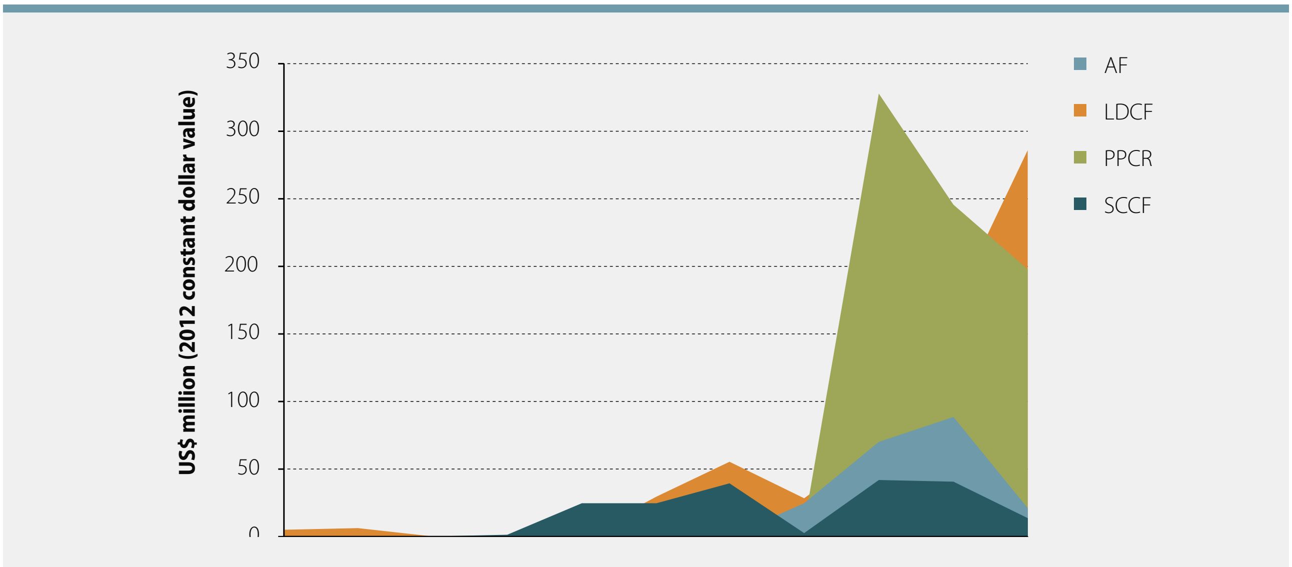
As illustrated in Figure 3.4 below, there has been a significant increase in adaptation finance by these funds since 2003. Even if they only represented 2 per cent of total adaptation commitments in 2013, the trend might be indicative of a larger focus on increasing resilience to the impact of climate change in developing countries.

This increase is mainly explained by the Pilot Program Climate Resilience, whose commitments peaked in 2011 with a total of US$336 million, while the LDCF experienced a more gradual but stable increase, reaching US$286 million in 2013, a 67 per cent increase from 2012. The SCCF's commitments have remained stable over the years and the Adaptation Fund reached a peak in 2012 with the approval of 14 new projects for a total amount of US$89 million.

9 Including the portion that contributes to both mitigation and adaptation (OECD 2014b).

10 While the US$ 0.6 billion figure also includes the EU Global Climate Change Alliance and National Climate Funds, the trends over time and sector and regional analysis presented in this section include the Climate Funds that focus only on adaptation namely, the Adaptation Fund, the Least Developed Countries Fund, the Special Climate Change Fund (adaptation window) and the Pilot Program for Climate Resilience.

Figure 3.4: Evolution of adaptation dedicated Climate Funds commitments* between 2003 and 2013 (constant US$ million)



Source: Climate Funds Update Website (accessed in June 2014)

**These refer to the funding approved for projects/programs*

The United Kingdom, Germany, and the United States are the biggest contributors to adaptation dedicated Climate Funds. Overall, countries have tended to respect their pledges, with 88 per cent of the total amount pledged being deposited into the funds. New pledges are needed to further catalyze these funds.

SECTORS AND REGIONS PRIORITIZED

As figure 3.3 shows, adaptation finance commitments were concentrated on a few sectors and regions. The majority, US$14 billion (58 per cent), went to activities related to water supply and management, followed by US$3 billion (14 per cent) for other climate-resilient infrastructure and coastal projection (Buchner *et al.* 2014).

In terms of recipients, US$22.3 billion, or 90 percent of the total, was invested in developing countries[11], while US$2.4 billion was invested in developed countries. The focus on developing countries mainly reflects the data sources considered: consideration of domestic budget for adaptation would change this split between countries.

Developing countries in East Asia and the Pacific, including China, were the largest recipient region (US$11 billion or 44 per cent) of total adaptation finance commitments in 2013 (Buchner *et al.* 2014).

DFIs committed more than three quarter of their resources to support water supply and management measures (US$14.2 billion or 66 per cent of their commitments) and for projects targeting the climate vulnerabilities of infrastructures, including coastal protection (US$3.3 billion or 15 per cent of their total) (Buchner *et al.* 2014).

Bilateral donors, in turn, targeted water supply and sanitation, general environmental protection[12], agriculture, fishing, forestry and rural development and disaster risk reduction and response activities. Together, these sectors account for 83 per cent of total bilateral adaptation-related ODA over 2010–2012 (OECD 2014c). More than half of adaptation-related bilateral activities target multiple environmental objectives. An average of 42 per cent of adaptation ODA also targets climate change mitigation, while 31 per cent targets biodiversity, and 20 per cent targets desertification objectives (see Annex A). Targeting multiple environmental objectives ensures that donors maximize the co-benefits of their interventions (see OECD 2009)

The share of projects targeting multi-sector activities is also large, in particular within adaptation dedicated Climate Funds (43 per cent), reflecting the prioritization of programmatic approaches that include a number of components each focusing on a different sector.

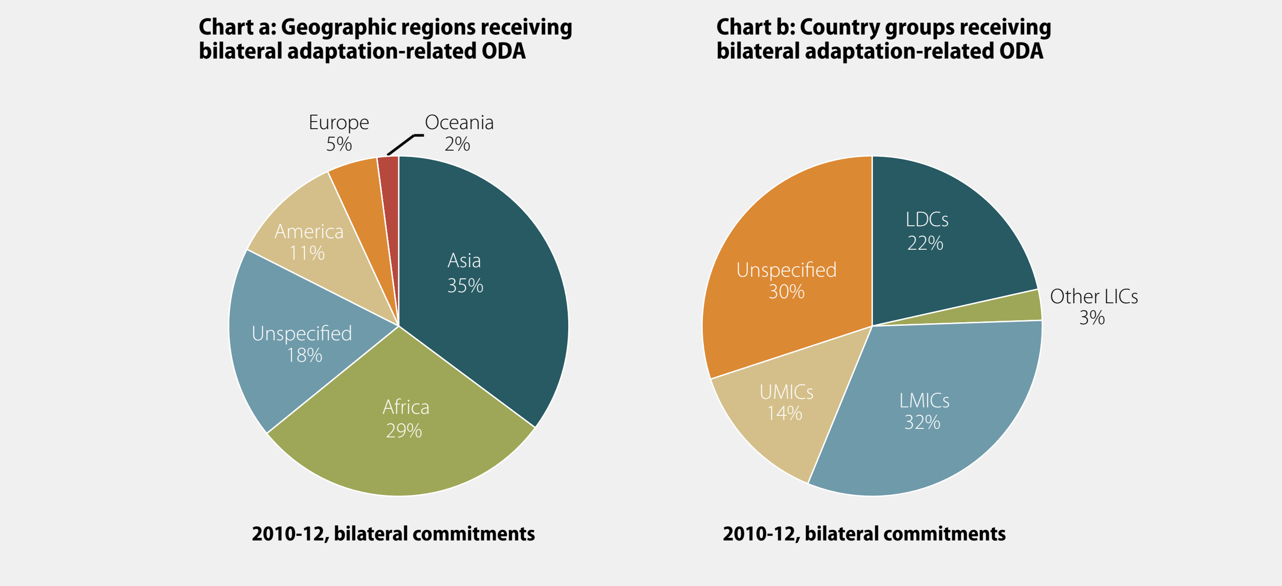
In terms of geographic allocation of adaptation targeted finance, DFIs invested mainly in East Asia and Pacific (48 per cent) and in Latin America and Caribbean (14 per cent) as well as sub-Saharan Africa (13 per cent) (Buchner *et al.* 2014). Climate Funds, instead, focus on sub-Saharan Africa (51 per cent) and South Asia (25 per cent) (Buchner *et al.* 2014, mainly based on ODI/HBF 2014).

11 That is, non-OECD countries and Chile / Mexico. Note that these are not exactly the same as the DAC ODA recipients, as Turkey is an OECD country but also an ODA recipient.

12 General environmental protection illustrates the importance placed by donors on adaptation-related policy formulation, research and education, and capacity-building in key economic infrastructure sectors, for example, water energy and agriculture.

Governments' bilateral adaptation-related ODA was mainly allocated to Asia. This reflects the investment behaviour of the largest provider, Japan, which primarily focused its activities in that region. Almost a fifth of all adaptation-related ODA is not specifically targeting a country or region; instead, this money flows to specific funds and programmes managed by international organizations, which in turn channel ODA to specific countries or to international NGOs and research institutions (see Chart a, Figure 3.5).

Figure 3.5: Recipients of adaptation-related ODA by geographic regions and country groups



Source: OECD DAC Statistics, November 2014 for further information see: http://oe.cd/Riomarkers

Note: The category unspecified is used when an ODA activity cannot be identified as targeting a single recipient, e.g. in the case where several countries or regions are targeted

By country group and in absolute terms, Middle Income Countries (MICs) receive the most bilateral adaptation-related ODA (Chart b). Upper MICs also receive on average the most adaptation ODA as a share of total commitments to these countries. However, LDCs and other Lower Income Countries (LICs) still receive a higher share of total adaptation related ODA (25 per cent) compared to their share of total mitigation related ODA (12 per cent; see OECD 2014e). Furthermore, per capita adaptation related ODA is also highest in LDCs (OECD 2014c).

Overall, this section has illustrated that there is evidence that adaptation-related finance has increased since the beginning of this decade (see Buchner *et al.* 2014, 2013, 2012b, 2011 and UNFCCC 2011)[13]. Furthermore, there is a clear indication that climate change considerations are being increasingly mainstreamed into development cooperation practices (OCED 2014d). However, the section also highlights that scaling up adaptation finance efforts to address current climate variability and projected climate change remains a pressing priority. As noted in the beginning of the section, a more comprehensive overview of adaptation finance flows would require inclusion of private finance flows and domestic spending on adaptation. Although limited data availability currently prevents this, the following two sub-sections briefly outline their potential roles in funding adaptation.

3.3.2 THE PRIVATE SECTOR

The Cancun Agreements (UNFCCC 2010b) invite, inter alia, public and private sectors to undertake and support enhanced action on adaptation at all levels, including under the Cancun Adaptation Framework, as appropriate, in a coherent and integrated manner, building on synergies among activities and processes, and to make information available on the progress made. They also agree that funds provided to developing country Parties may come from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources.

13 Since the first assessment carried out by Buchner *et al.* (2011), knowledge and availability of data on adaptation finance has increased. Improvements in tracking approaches and methodologies (for example, AfDB *et al.* 2012 and 2013, Ecofys & IDFC 2012 and 2013, and the introduction of the OECD DAC climate adaptation Rio Marker in 2010 (OECD 2011)), as well as research efforts on specific climate flows (for example, Nakhooda *et al.* 2013 on Fast Start Finance) are the main drivers of this development.

There are no estimates of the current levels of private sector adaptation finance as tracking this remains challenging, and no common and agreed methodology has been established (Stadelmann *et al.* 2013). There are ongoing efforts to address this gap and the OECD is currently developing improved methodologies (OECD 2013).

In a review of the adaptation projects funded by the LDCF and the SCCF focusing on private sector, Biagini & Miller (2013) find a need to better understand and advance the supply of adaptation services and products, as well as the demand for enhanced resilience. A key part of this will be creating an enabling environment for private sector adaptation to support supply and demand side operators, which will require public intervention to address various market, information and policy failures.

This means that the role and opportunities for the private sector in adaptation will be different to mitigation. This is because adaptation is often needed most in non-market sectors or is focused on public goods that benefit many. The highest adaptation needs are often in markets that are not operating effectively or where risks are high. Adaptation is often local and diffuse, involving many actors; it also involves future benefits. All of these factors reduce the potential for direct private sector investment, especially in the most vulnerable countries. It is also clear that the private sector alone will often not provide a desirable level of adaptation due to costs, incentives, the nature of beneficiaries and resource requirements. This could lead to maladaptation, where vulnerability is merely shifted.

THE ROLE OF DOMESTIC GOVERNMENT BUDGETS IN FUNDING ADAPTATION

Recipient-focused climate finance mapping efforts such as the Climate Public Expenditure and Institutional Reviews (CPEIR) suggest that developing countries prioritize adaptation in their total budgets allocated to climate change. In Thailand, for instance, spending on adaptation is estimated at around 68 per cent of the total government budget allocated to climate initiatives (2009–2011) (Government of Thailand 2012). The total government budget allocated to climate initiatives represents 2.7 per cent of the overall government budget (Government of Thailand 2012). In Nepal, annual expenditure on all climate change-related activities constitutes approximately 2 per cent of Gross Domestic Product and around 6 per cent of government expenditure. Domestic efforts for adaptation accounted for 76 per cent of the total governmental budget allocated to climate initiatives over the five years reviewed in the CPEIR study (2007/8-2011/12) (Government of Nepal *et al*. 2011). A number of tracking difficulties and issues emerged from these and other country-level studies, (including Ampri *et al.* (2014), and Terpstra *et al.* (2013)) and it should be noted that national level estimates are associated with considerable uncertainty due to difficulties rooted in the different definitions of adaptation finance and inter-linkages of adaptation with development finance or environment and natural resource management activities.

3.4 INDICATIVE FINDINGS ON THE ADAPTATION FUNDING GAP AND OPTIONS TO BRIDGE IT

Acknowledging the challenges in directly comparing adaptation needs in future years (2020–2050) with the finance available in 2013, it is clear from the analysis in this chapter that there is likely to be a major adaptation funding gap after 2020 unless scaled-up, new and additional finance becomes available. The exact scale of the funding gap is difficult to estimate and involves complex issues around potential needs versus sources of finance.

Box 3.1 provides an illustrative example of how innovative sources of funding could contribute to bridging the adaptation funding gap, based on an update of the United Nations Secretary General's high level Advisory Group on Climate Change Financing.

Box 3.1: The potential role of innovative sources in bridging the adaptation funding gap: an update of the High-Level Advisory Group on Climate Change Financing

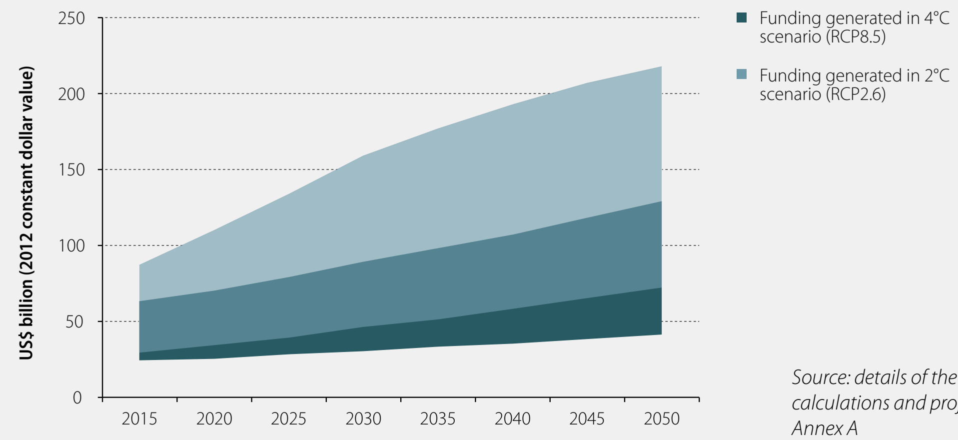
In the process of negotiating the post-2012 climate agreement a number of parties introduced concepts to raise additional revenue streams to support mitigation and adaptation actions by developing countries[14]. These proposals went beyond traditional development aid transfers and were subsumed under "alternative" or "innovative" sources of climate finance. Parties to the Copenhagen Accord recognized the need to further investigate and study "the contribution of the potential sources of revenue, including alternative sources of finance" to meet the US$100 billion commitment (UNFCCC 2009). To explore the role and potential of these alternative sources in funding adaptation and mitigation actions in developing countries, United Nations' Secretary General Ban Ki-Moon established in 2009, a High-Level Advisory Group on Climate Change Financing (AGF). The final report of this group, released in November 2010, identifies several sources and instruments to be implemented to reach the US$100 billion commitment by 2020. The report came to the conclusion that achieving the US$100 billion commitment is "challenging but feasible".

While the AGF report in particular studied the revenue potential of different sources in the pre-2020 context, this estimate assesses how much funding could be raised during the period 2015–2050 from a selected set of sources using the same assumptions and scenarios as in the AGF report: the international auctioning of emissions allowances and the auctioning of allowances in domestic emissions trading schemes; a carbon levy; revenues from international transportation; a wires charge; and the financial transaction taxes (details of the calculations and projections are explained in Annex A).

The range of funding to be potentially generated from these five sources is large and depends on the difference between the low and the high share scenarios (see Annex A for details). Figure 3.6 displays the range of funding generated in both the 2°C and 4°C scenarios. It illustrates the wide-ranging amount that can be generated through the implementation of levies in these sectors.

The analysis led by the AGF in 2010 on the potential contribution of innovative sources to reach the US$100 billion target by 2020 is particularly relevant in the context of the increasing needs for adaptation in developing countries. The estimates displayed in Figure 3.6 illustrate the high potential of these sources in contributing to meeting the adaptation needs challenge and to ensuring that funding for adaptation activities is additional to current ODA and also predictable. The estimates highlight that between USD26 billion and USD115 billion could be raised by 2020. Figure 3.6 underlines the importance of ambitious mitigation commitments to tap the full potential of these sources in the immediate term, as funding that could be potentially generated under this scenario ranges from about US$70 billion to US$220 billion. Under the low emission scenario the US$100 billion target per year could be met almost immediately assuming the high share scenario and would be constantly available until 2050.

Figure 3.6: Range of funding generated in Annex-I country Parties from innovative sources in a 4°C world (IPCC RCP8.5 scenario) and in a 2°C world (IPCC RCP2.6 scenario) in the low and high share scenarios



Source: details of the sources, calculations and projections in Annex A

The analysis also point to several key areas, where further consideration is needed, including in relation to the future costs of adaptation, international finance flows particularly from the private sector, and on bridging the adaptation gap

The current global estimates of the costs of adaptation report a range of US$70 billion to US$100 billion per year globally by 2050 (for developing countries). The findings of this review suggest these values are likely to be a significant underestimate, particularly in the years 2030 and beyond. As a minimum, it seems likely that the costs of adaptation will be two to three times higher than current global estimates. The country studies available indicate much higher costs towards 2050, plausibly four to five times higher than current estimates, and highlight that adaptation needs are not equally distributed. In relative terms, LDCs and SIDS are likely to have much higher adaptation needs, and a failure to implement early adaptation in these regions will have disproportionate impact by widening the existing adaptation deficit.

It is also clear that adaptation needs will rise more quickly under higher emission scenarios, such as under a 4°C rather than a 2°C pathway. Indicative modelling indicates that the emissions-dependent adaptation gap could be large with costs potentially doubling under a 4°C pathway around mid-century (relative to a 2°C pathway), due to the earlier exceeding of the 2°C goal, the faster rates of climate change, and the greater levels of anticipatory adaptation for future high levels of change.

The review of current adaptation finance reveals an encouraging story over recent years. Public adaptation-related finance, based on available data to date, is estimated to be US$24.6 billion (range US$23-26 billion) in 2012/13, of which 90 per cent was invested in non-OECD countries, including Chile and Mexico. This represents a large increase over recent years. It is unclear, however, how much of this identified adaptation finance is "new and additional", particularly given contested understandings amongst governments and stakeholders on how to define this. Past research on public climate finance contributions (during the fast start finance period) has raised questions about whether this finance is additional to the existing pipeline of projects and funding. Nonetheless, it is clear that climate change considerations are being increasingly mainstreamed into development co-operation practices, which can contribute to addressing current as well as future adaptation gaps.

The gap analysis in this chapter only matches current public funding with projected adaptation costs and needs. It may, therefore, underestimate the contribution of the private sector in developing countries in directly carrying out and supplying adequate adaptation measures in response to the early impacts of climate change. In addition, no attempt has been made at indicating the share of the adaptation funding gap to be covered through international and public finance flows or to make a distinction between funding for development gaps and funding for adaptation gaps. Nonetheless, the analysis underscores the need for predictable and additional sources of funding to bridge the adaptation gap and the central role of the Green Climate Fund in contributing towards bridging the adaptation funding gap.

14 See for example: Swiss Global Carbon Adaptation Tax submission at the UNFCCC, the IATAL submission from the Maldives on behalf of the LDCs or Mexico's World Climate Change Fund also submitted at the UNFCCC.

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04

CHAPTER 4

TECHNOLOGY GAPS

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4.1 INTRODUCTION

Technology development, transfer, and diffusion (dissemination and uptake) are priorities on the international agenda of adaptation to climate change. Discussions in the context of the United Nations Framework Convention on Climate Change (UNFCCC) regarding technologies historically focused on mitigation but technologies for adaptation have recently been brought squarely in (UNFCCC 2010). Commitments to scale up efforts on technology transfer were made in 2008 with the Poznan Strategic Programme on Technology Transfer (UNFCCC 2008). This led to the Technology Mechanism in 2010, which aims to "facilitate enhanced action on technology development and transfer to support action on mitigation and adaptation".

The Technology Executive Committee and the Climate Technology Centre and Network (CTCN) implement the Technology Mechanism (see Box 4.1).

Box 4.1: The Climate Technology Centre and Network (CTCN)

The Climate Technology Centre and Network consists of a climate technology centre (CTC) and a network composed of institutions capable of responding to requests from developing countries related to the development and transfer of climate technology. The mission of the CTCN is to stimulate technology cooperation and improve climate technology development and transfer. CTCN assists developing countries in a way that is consistent with their respective capabilities, national circumstances and priorities, and undertakes its work to strengthen the capacity of developing countries to identify technology needs. The CTCN is hosted by UNEP in collaboration with the United Nations Industrial Development Organization.

(see http://unfccc.int/ttclear/templates/render_cms_page?TEM_ctcn)(see http://unfccc.int/ttclear/templates/render_cms_page?TEM_ctcn)

International attention to the role of technologies in addressing adaptation challenges and climate risks is a major motivation for activities in developing countries. These include Technology Needs Assessments (TNAs), emerging activities under the CTCN, Low Carbon and Climate Resilient Development Strategies and National Climate Strategies (see Box 4.3).

Adaptation technology gaps can be defined as the difference between technologies for adaptation actually implemented and a societally set target for implementation of technologies for adaptation. This definition is equivalent to the generic definition proposed in Chapter 2 of this report, which reflects the multidimensional definition of technologies for adaptation that overlaps significantly with the definition of adaptation. This also makes it difficult to measure or quantify the adaptation technology gap separately from the adaptation gap. However, we can identify perceived gaps by the countries based on available technology needs assessments, and requests to technology support mechanisms.

In this chapter, we summarize and analyse key gaps related to technologies for adaptation, drawing mainly on the findings of recent needs assessments, as well as from scientific literature in the field. The chapter begins with a brief summary of how technologies for adaptation are defined, followed by an overview of how technologies can contribute to reducing climate change risks. The chapter continues with an overview of the current landscape of adaptation technology gaps, including countries' priorities and perceived gaps in transfer, diffusion and innovation. The next sections present barriers that have been identified and an enabling framework for the transfer of adaptation technology. It outlines potential targets for adaptation technologies. The chapter has a concluding section.

4.2 DEFINING TECHNOLOGIES FOR ADAPTATION

Adaptation is not merely a matter of making adjustments to technical equipment but also includes organizational and social dimensions. The Intergovernmental Panel on Climate Change (IPCC 2000), in its special report on Methodological and Technological Issues in Technology Transfer, defines technology as "a piece of equipment, technique, practical knowledge or skills for performing a particular activity". A UNFCCC report on the development and transfer of technologies for adaptation to climate change proposes the following definition for adaptation technology: "the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change" (UNFCCC 2010).

It has become common to distinguish three categories of technologies for adaptation: hardware, software and orgware (Boldt *et al.* 2012, Glatzel *et al.* 2012, Thorne *et al.* 2007). Hardware refers to "hard" technologies such as capital goods and equipment, including drought-tolerant crops and new irrigation systems. Hardware technologies are often expert driven, capital-intensive, large-scale, and highly complex (Sovacool 2011, Morecroft and Cowan 2010, McEvoy *et al.* 2006). They can also be more simple technologies that are readily available, involving traditional and local knowledge, but which for some reason have not been applied by a larger number of users yet. Software refers to the capacity and processes involved in the use of technology, and covers knowledge and skills, including aspects of awareness-raising, education and training. The concept of orgware relates to ownership and institutional arrangements of the community/organization where the technology will be used. Annex B to this chapter provides examples of the different technology categories for various sectors, and different key risks.

With this understanding of adaptation technologies it is clear that technologies are already embedded in many existing approaches to adaptation. For example, ecosystem-based adaptation (EbA) involves a wide range of ecosystem management activities to increase resilience and reduce the vulnerability of people and the environment to climate change. The EbA approach includes various options that can be categorized as adaptation technologies, including protected area systems design, the restoration of key habitats to reduce vulnerability to storm damage, and the establishment of water reservoirs through the restoration of forests and watersheds.

The UNFCCC has identified the role of technologies for adaptation within four different stages of adaptation: information development and awareness, planning and design, implementation, and monitoring and evaluation (Klein *et al.* 2006). Table 4.1 provides an overview of the key stages in adaptation and exemplifies the role technologies have in reducing risks for the coastal zone sector.

Table 4.1: Overview of the role of technologies in the key stages of adaptation in reducing climate risk for the coastal sector

Stage of adaptation	Role of technologies, examples from the coastal zone sector
Technologies to collect data, provide information and increase awareness for adaptation to climate change	Mapping and surveying, Satellite remote sensing, Airborne laser scanning (lidar), coastal vulnerability index, computerised simulation models.
Planning and design	Geographical information systems (GIS) for spatial planning.
Implementation	Dykes, levees, floodwalls, Saltwater-intrusion barriers, Dune restoration and creation, Early-warning systems.
Monitoring and evaluation	Basically the same technologies as in the first stage. Effective evaluation requires a reliable set of data or indicators, collected at regular intervals using an appropriate monitoring system.

Based on Klein et al. (2006)

Adaptation technologies can also be viewed in terms of technological maturity. Here a distinction can be made between traditional technologies, modern technologies, high technologies, and future technologies (Klein *et al.* 2006). Traditional technologies are technologies that have been developed and applied throughout history to adjust to weather-related risks. It can be change of agricultural management practices, the building of houses on stilts or construction of dykes to protect against flooding. Modern technologies are those created since the onset of the industrial revolution in the late 18th century. They make use of new materials and chemicals, and of improved designs. High technologies derive from more recent scientific advances, including information and communication technology, earth observation systems providing more accurate weather forecasts, geographical information systems, and genetically modified organisms. Finally, we can look towards future technologies that are still to be developed, for example crops that need little or no water, or a malaria vaccine.

4.3 THE ROLE OF TECHNOLOGIES IN REDUCING RISKS

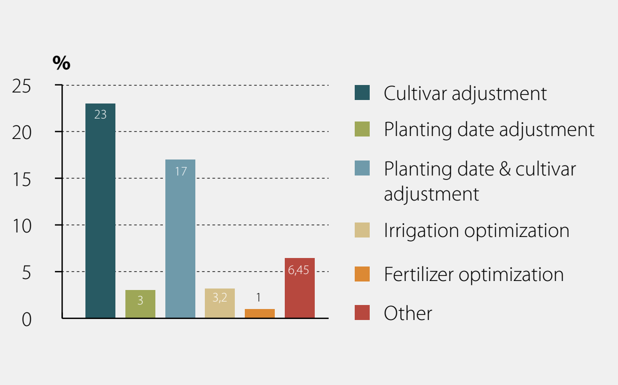
Technologies for climate change adaptation have the potential to play a substantial role in improving social, economic, environmental, and management practices in sectors vulnerable to climate change. It is difficult to assess the extent to which technologies are transferred and diffused, however, in the process of adaptation to climate change. Aspects included in the definition of technology—such as training, capacity building, education, and institutional and organizational aspects of technology— further complicate assessing and quantifying the transfer, diffusion and deployment of technologies and their contribution to risk reduction. Using financial flows could be one (limited) proxy for the comparison over time. Another complicating factor in computing the extent of technology application is that most adaptation technologies are essentially either changes to existing systems or systematic changes that integrate new aspects into current systems.

In the agricultural sector a core challenge for adaptation technologies is to strengthen the ability to produce more food using fewer resources under more fragile production conditions (Lybbert and Sumner 2012). Agricultural production is intrinsically linked with climate in terms of temperatures and precipitation, and even without climate change increasing agricultural productivity requires technological advances. In many developing countries, water availability is projected to decline radically with climate change and population growth in the next few decades (Jiménez Cisneros *et al.* 2014). With changed rainfall patterns and warmer conditions, the future of the agricultural sector in Africa, for example, is even more dependent on improved access to irrigation and improved water management practices and efficiency.

In addition to other adaptation technologies on sustainable water use and management, the efficiency and extension of existing irrigation systems needs to be improved where cost-effective, while, in many cases, new systems need to be installed. In others, land may simply not be arable any longer or there will be a need to introduce new crops based on altered climate conditions.

Figure 4.1 reflects simulated yield benefits from using different adaptation technologies in crop production. These technologies could, either separately or in combination, significantly reduce the impact of climate change on crop production and increase the benefits of positive changes. Box 4.2 provides examples of the use of scientifically developed seeds.

Figure 4.1: Benefits from adaptation technologies - examples from the agricultural sector



Source: Based on Porter et al. (2014)

For the water sector, ensuring adequate water supply under climate change is projected to require significant investment. Yet many of the technology options in the water sector are "no regrets" technologies (Elliot *et al.* 2011) generating net social and/or economic benefits even in the absence of anthropogenic climate change (see Box 4.4). Adaptation technologies addressing issues such as the contamination of drinking water supplies, water resource diversification, and conservation will generally provide benefits even in the absence of climate change.

Box 4.2: New seed technology for agricultural adaptation: experiences from Cameroon, Zambia, and Madagascar

Sustaining agriculture within the context of a changing climate is critical for most African countries given the dependence of large proportions of the population on farming. One common application of technology to agricultural adaptation is the use of scientifically developed seeds—certified, hybrid, or early-maturing to maintain or improve yields.

In Madagascar, rice varieties that mature in four months (as opposed to five or six) have been introduced. They stand a greater chance of reaching maturity before the height of the cyclone season, increasing the probability of a decent harvest and ensuring seed will be available to plant in the following season. The early maturing Open Pollinated Varietal (OPV) rice seeds have the secondary benefit of improved yields: farmers in the Analanjirofo and Antsinanana regions of eastern Madagascar explain that an average annual yield for their traditional seeds would be around 100kg, whereas with the early maturing OPVs it is around 225kg.

In the drought-prone Southern Province in Zambia, the use of early maturing seeds in conjunction with training in conservation agriculture to conserve scarce water resources (such as minimum-till land preparation and mulching) is improving yields and food security. The Least Developed Countries Fund (LDCF)-funded project is in its early stages, but it is explicitly targeting women farmers and therefore contributing towards gender equality as well in the districts participating.

In Cameroon, improved varieties for maize (for example, 8034 and 961414) and cassava have been promoted by farmers' organizations primarily as commercial crops for sale. The combination of greater yields and access to markets brokered by the farmers' organizations has increased incomes and also financial capital, which can act as a cushion in years of poor production due to poor farming weather.

Strong training and ongoing technical support in the use of the new seed technologies is common across all three case studies. New seed technologies are by no means a panacea for agricultural adaptation: improved seed breeds typically require inputs (such as fertiliser and insecticide) to meet maximum yields, which can create a financial barrier; and cultural norms in Madagascar and Zambia are to recycle seeds, whereas certified seeds need to be replaced regularly otherwise yields decline. Additionally, in Madagascar the seed market is very underdeveloped, impeding accessibility for farmers.

These differing examples show that the application of various seed technologies can support agricultural adaptation but that modification for context is required.

There are already many potential adaptation technologies available for reducing the key risks of climate change to existing agricultural systems. These are often modifications to the existing options to accommodate the impact of climate change. Implementing such technologies are likely to have substantial benefits under climate change if systematic changes in resource allocation are considered. Investment in technology-based adaptation (for example seeds, dams, and irrigation) are complicated by the fact that it remains difficult to predict the future impact of climate change, especially on a local scale. Estimating the costs and benefits of adaptation technologies is made more difficult by uncertainties associated with the lack of a consensus in climate change projections and with incomplete information on the path of economic growth and technological change (World Bank 2010). Decisions about investments in adaptation technologies with a horizon of maybe 20, 30 or 40 years—including drainage, water storage, bridges and other infrastructure—will have to be based on unsure information given the degree of variation in climate change projections and other uncertainties, including projections on economic growth. Faster economic growth will put more assets at risk at various levels of society across the world and possibly increase the potential for damage, but as a result of higher levels of investment and technical change, it could also result in higher levels of flexibility and of capacity to adapt to climate change.

4.4 CURRENT LANDSCAPE OF ADAPTATION TECHNOLOGY GAPS

We cannot measure or quantify an overall adaptation technology gap because of the multidimensional definition of technologies for adaptation (see section 4.2) and lack of detailed information on the potential technologies may have to contribute to the reduction of climate risks at an aggregate level. The technology needs assessments and action plans available, however, establish the basis for identifying and analyzing some of the key technology gaps perceived by countries.

Box 4.3: Technology Needs Assessments

Technology needs assessments (TNAs) are a set of country-driven activities that identify and determine the mitigation and adaptation priorities of developing countries. The TNA process involves different stakeholders identifying barriers to technology transfer and measures to address them through sector analyses.
As part of their TNAs, countries have prepared technology action plans (TAPs) and project ideas. A TAP is an action plan selecting one of several options for groups of measures to address barriers to the development and transfer of a prioritized technology. In the context of their TNAs, countries envisage project ideas as concrete actions for the implementation of their prioritized technologies.

More information can be found at: **http://unfccc.int/ttclear/templates/render_cms_page?TNA_home**

Table 4.2 lists the adaptation requests submitted to the CTCN at the time of writing. Given the relatively limited number of requests submitted so far and the lack of geographical and sectoral coverage, the table should not be seen as fully representative of gaps in technologies for adaptation. The types of requests submitted provides a good illustration of the broad perception of what constitutes technologies for adaptation, though, and reflects existing adaptation technology definitions and where technology gaps exist.

Tabel 4.2: Overview of requests for technical assistance on adaptation submitted to the CTCN

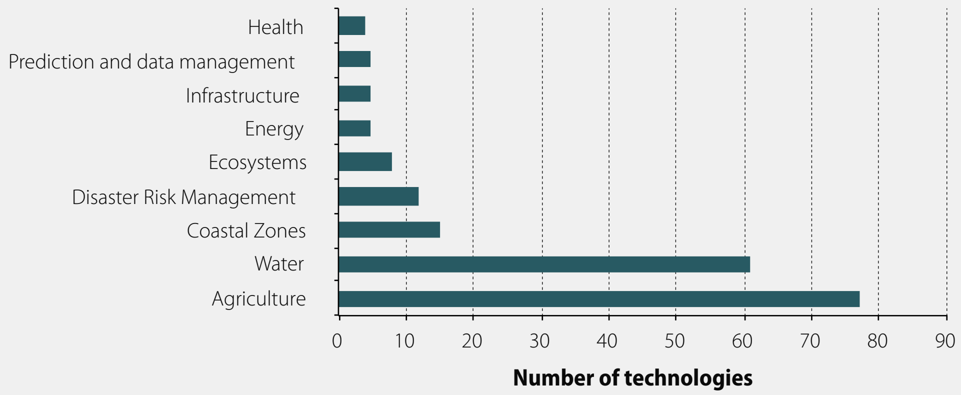
Country	Sector	Request title
Afghanistan	Cross-sectoral	Technical support and advice for the identification of technology needs
Chile	Ecosystems	Design of Biodiversity Monitoring Network in the context of Climate Change
Colombia	Cross-sectoral	Development of a National System of Indicators for Adaptation to Climate Change
Honduras	Ecosystems	Strengthening local capacities at Cuyamel Omoa Protected Area
Ivory Coast	Cross-sectoral	Implementation of an environmental information system which is able to support the selection of a suitable sustainable development policy and promote optimal management of climate change issues
Mali	Cross-sectoral	Strengthening the implementation of climate change adaptation activities and clean development in rural communities in Mali
Pakistan	Agriculture	Propagation of Crop Production Process for Productivity Enhancement
Pakistan	Cross-sectoral	Technical guidance and support for conducting Technology Needs Assessment (TNA)
Syria	Cross-sectoral	Technology Needs Assessment (TNA) for climate change

Source: CTCN (2014)

4.4.1 SECTORS AND TYPES OF TECHNOLOGIES PRIORITIZED BY COUNTRIES

Recent analyses of technology needs assessments for adaptation in developing countries (Trærup and Christiansen 2014, UNFCCC 2013a, 2013b) show that most countries identify water and agriculture as their priorities (see Figure 4.2). This is consistent with findings from earlier technology needs assessments and national adaptation programmes of action (NAPAs) (Fida 2011, UNFCCC 2009).

Figure 4.2: Sector distribution of 192 priority adaptation technologies identified in 25 TNA reports (in numbers)

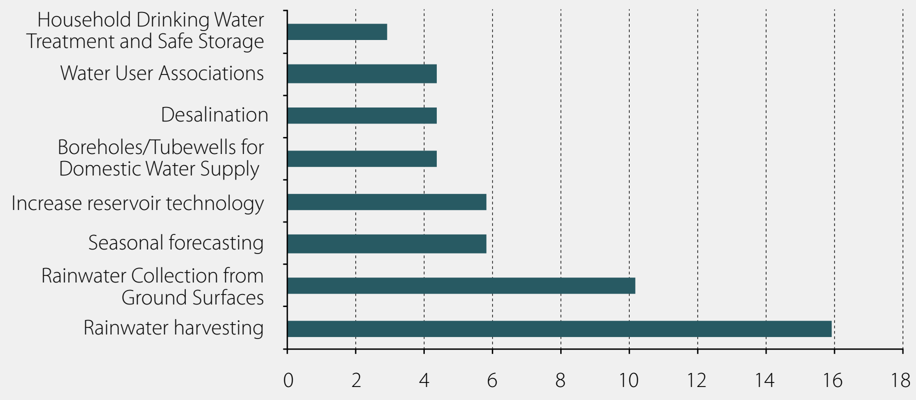


Source: Based on data collected from TNA reports available at: www.tech-action.org

When identified priority technologies within the individual sectors are compared, the relative weight of hardware, software and orgware varies significantly. In particular, the water technologies identified (Figure 4.3) were significantly more 'hardware-intensive' (77 per cent hardware technologies) than, for example, the agriculture sector (36 per cent hardware technologies).

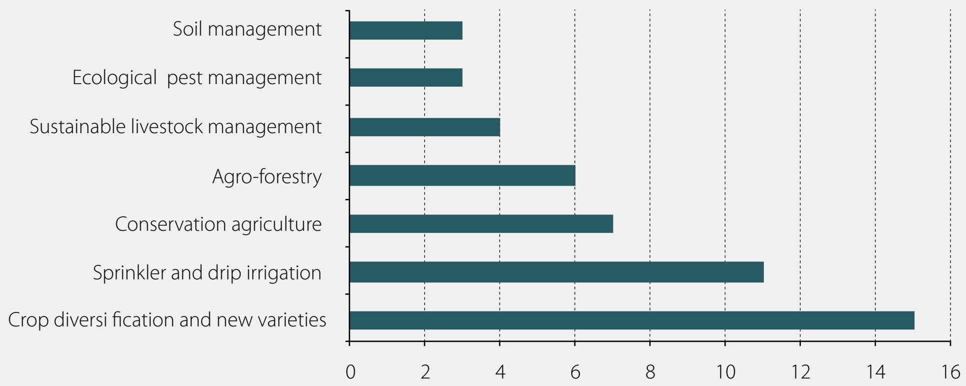
This difference is probably explained by the individual characteristics of each sector: technologies related to water tended to be supply-focused (as with water harvesting and storage from roofs, small dams and reservoirs to store run-off, and with desalinization and the restoration/construction of wells) rather than demand/management-focused (like water-user organizations or integrated watershed management). By contrast, the technologies identified for agriculture (Figure 4.4) tended to be more complex and focused on resource management and integrating aspects of both hardware and software: these include increasing irrigation efficiency through improved management; developing and disseminating drought-resistant crops and cropping systems; implementing integrated agriculture systems such as agro-forestry and mixed farming; and improving extension services and so on. Only rarely were the agriculture technologies identified purely hardware-focused, for example, as investments in modern irrigation systems or terracing, and even then some level of changed practice or knowledge transfer would be an integral part of the technology implementation (although this may not necessarily be stated in the documentation).

Figure 4.3: Percentage distribution of priority adaptation technology needs within the water sector



Source: Based on data collected from 25 TNA reports available at: www.tech-action.org

Figure 4.4: Percentage distribution of priority adaptation technology needs within the agricultural sector



Source: Based on data collected from 25 TNA reports available at: www.tech-action.org

4.4.2 GAPS IN TECHNOLOGY TRANSFER, DIFFUSION AND INNOVATION

To illustrate where the different adaptation technology gaps exist, Table 4.3 depicts the nature of the technology needs countries identified and, thus, implicitly the gaps they have in terms of transfer, diffusion and innovation. The same technologies can appear in several areas acknowledging different gaps in terms of transfer, diffusion, and innovation within the same sector. One country may have efficient and affordable irrigation systems available, while another may need access to more efficient irrigation systems. The table also reflects that, in terms of adaptation, technologies are often familiar and applied elsewhere. For example, water saving technologies well known in one region of a country may be applicable and relevant but not accessible in another region.

Table 4.3: Adaptation technology transfer, diffusion and innovation gaps for selected sectors

Technology gap	Water	Agriculture	Coastal zone	Disaster risk management
International transfer	desalinisation techniques, irrigation techniques	agro-meteorological techniques, water efficient irrigation systems	hazard insurance, salt-resistant crops, building codes, improved drainage, desalination systems, flood hazard mapping, artificial underwater reefs	forecasting, early warning and contingency plans, reconstruction planning
Gaps in technology diffusion and uptake	rain water harvesting techniques, ponds, wells, reservoirs	conservation agriculture, crop diversification, ecological pest management, floating gardens	dykes, seawalls, tidal barriers, development planning in exposed areas, wetland restoration	community based early warning systems, planting mangroves to reduce the risk posed by tidal surges
Technology innovation gaps	increased water use efficiency, desalination techniques, waste water treatment	new crop varieties, bio technology (e.g. drought-tolerant and early maturing food crops/varieties), improved irrigation systems	building codes, early warning systems, flood resistant building materials	tools in meteorological, hydrological and agricultural drought mapping, assessment and monitoring, and early warning systems

Source: Based on data from identified technologies in TNAs available at: www.tech-action.org

4.4.3. GAPS IN TECHNOLOGY BY SECTOR AND TECHNOLOGY MATURITY

Table 4.4 shows the technological maturity of the technologies identified in the TNAs of 25 countries. There is a clear difference in the distribution of technologies between the three categories. Traditional technologies dominate for the agricultural sector; modern technologies dominate for the water, coastal zones, ecosystems, and health sectors; and high technologies dominate for disaster risk management, energy, infrastructure, and prediction and data management. The majority of identified technology gaps are within the category of modern technology. The remaining technologies are distributed close to equally between traditional and high technologies, with slightly more gaps in traditional technologies. Comparing this to an earlier assessment by the UNFCCC (2009), which is reflected at the bottom line of Table 4.4, there seems to be a shift in demand from traditional technologies towards more modern technologies.

Table 4.4: Technological needs by sector and technological maturity

Sectors	Technological maturity			Technologies	
	Traditional	Modern	High	No.	%
Agriculture	55.8	29.9	14.3	77	40.1
Water	1.6	90.2	8.2	61	31.8
Coastal Zones	13.3	80	6. 7	15	7.8
Disaster Risk Management	0	8.3	91. 7	12	6.3
Ecosystems	12.5	75	12.5	8	4.2
Energy	0	0	100	5	2.6
Infrastructure	0	20	80	5	2.6
Prediction and data management	0	0	100	5	2.6
Health	0	75	25	4	2.1
Total, no	47	101	44	192	
Total, %	**24.5**	**52.6**	**22.9**		**100**
Total, % (previous assessment*)	40.6	34.5	24.8	165	

Source: Based on data from 25 countries' reported technology needs in their TNAs.
**Based on UNFCCC (2009)*

4.5 BARRIERS AND ENABLING FRAMEWORKS

A number of barriers remain in terms of the transfer and diffusion of adaptation technologies. Together, these barriers set the stage for exploring the policy responses necessary to support the further development, transfer, and diffusion of technologies for adaptation. The barriers discussed are relevant not only to existing technologies but also to the innovation of future technologies.

For adaptation—irrespective of the sector or technology—almost all the barriers identified in past technology needs assessments fall within certain categories: economic and financial; policy, legal and regulatory; institutional or organizational capacity; and technical barriers to the development and transfer of the technologies countries prioritized (UNFCCC 2013b). Within the category of economic and financial barriers, a major barrier identified by countries was their lack of—or inadequate access to—financial resources (90 per cent). For the policy, legal and regulatory barrier category, the most common barrier was an insufficient legal and regulatory framework (85 per cent). For the institutional and organizational barrier category, the barrier most often reported was limited institutional capacity (90 per cent); while for the technical barrier category, the most commonly reported barrier was system constraints (68 per cent), such as capacity limitation. For example, a Technology Needs Assessment for Lebanon identified some of the key barriers in the agricultural sector as: the high cost of imported patented plant material; the absence of a crediting system; an inappropriate land tenure system; and the shortage of institutional arrangements for subsidies (MoE/URC/GEF 2012).

Lybbert and Sumner (2010) analyzed the policy and institutional changes needed to encourage the innovation and diffusion of agricultural practices and technologies to developing countries, and found that a major barrier to the use of technologies—for example for new seed varieties and crops—occurs at the stage of adopting the new technology where access to and use of new technologies by poor farmers is impeded by several factors. These include: static, poorly functioning or poorly integrated markets; weak local institutions and infrastructure; inadequate or ineffective extension systems; and missing credit and insurance markets. Confirming this, other studies found that it is not the availability of technologies but rather their adoption and diffusion at a local level that poses a challenge for their role in adaptation.

Lack of information presents a barrier to the effectiveness and use of technologies in cases where different groups of stakeholders—involved at different stages of the adaptation planned—need technological information, which is sometimes itself limited and not accessible. Many technology users in developing and least developed countries have few resources to set aside for the purchase of new technologies (Practical Action 2011, Adger *et al.* 2007, Smithers and Blay-Palmer 2001).

It is also evident that the growth of funding for agricultural research has slowed down over time. Despite numerous cost benefit studies reporting on high returns from investment in agricultural research and development (Evenson 2002, Alston *et al.* 2000), there has been a general decline in spending on public sector research and development in agriculture in recent decades (Alston *et al.* 2009). In the United States, public spending on agricultural research and development has fallen to 0.8 percent per year in 2007 from about 2.0 percent in the 1950s (Alston *et al.* 2009).

Current proposals in the area of technology needs assessments show that there is awareness that stand-alone technologies such as physical structures and equipment—are seldom sufficient in themselves but need to be supported by an enabling framework, something recognized in development studies in general.

Box 4.4. Technology Needs Assessment in Small Island Developing States (SIDS)

Mauritius is one of the two SIDS that participated in the first phase of the TNA project. The overarching objective of the TNA project in Mauritius was to improve climate preparedness using an evidence-based approach to better position Mauritius to attract climate finance for technology transfer and the scaling up of proven climate-sound technologies. The scaling up of micro-irrigation (gravity fed drip, mini and micro sprinkler irrigation) among small planters was selected as a "no regrets" technology for adaptation (Deenapanray and Ramma 2014). The most common irrigation systems used for irrigation in vegetable, fruit, and flower production are the drag line, mini-sprinkler and portable/semi-portable sprinkler systems. Due to increasing scarcity of water, however, there is a tendency to shift towards drip irrigation systems that have a higher water efficiency rate (30–40 per cent) than the sprinkler system. Mauritius has had various experiences with drip irrigation systems such as the family drip irrigation system (2001) and the Kenya Agricultural Research Institute (KARI) Drip Kit (2009), both designed for small-scale farming. The latter was evaluated under local conditions and was found to help save on water and on nitrogen fertiliser while improving crop yield by up to 35 per cent, enhancing the income of farmers and reducing the environmental impact of chemical loading.

Using the evidence-based outcomes of the TNA project, the Food and Agricultural Research and Extension Institute (FAREI), has developed a project for scaling up of the micro-irrigation technologies to assist vulnerable small-scale farmers in the drought prone areas of Mauritius.

4.6 POSSIBLE TARGETS FOR ADAPTATION TECHNOLOGIES

As is the case for all adaptation planning, key considerations when setting targets for adaptation technologies include aspects related to the availability of appropriate technologies; access to appropriate technologies in terms of capacity related to financing, operation and maintenance; the acceptability of the technologies to stakeholders (economically and culturally); and their effectiveness in strengthening overall resilience to climate risks (van Aalst *et al.* 2008, Adger *et al.* 2007, Dryden-Crypton *et al.* 2007)

When identifying targets for the transfer and diffusion of adaptation technologies, there is as much a need to distinguish between different timescales—such as when the target should be reached and when required technologies are available and accessible—and levels of certainty and costs, as there is to define any targets for the implementation of other adaptation initiatives. There should be a distinction made as well between "no regrets" options justified by current climatic conditions, and "low-regrets" options made because of climate change but at minimal cost (cost-effective and proportionate).

Considering the existing definitions of technologies for adaptation, introducing "technology approaches" into adaptation and development practice may not necessarily lead to major changes in priorities or in the actual measures implemented compared to those shown in earlier and current adaptation priority assessments such as NAPs, NAPAs, and National Communications.

The broad definition of technologies raises other issues in relation to the work under the UNFCCC (Olhoff 2014). The challenges in clearly distinguishing adaptation technologies from adaptation measures imply there could be risks in driving processes for adaptation under the technology pillar and the work under the adaptation pillar simultaneously. Therefore, there is a need for coordination and the exchange of information between these two pillars of work.

The Cancun Adaptation Framework provides an opportunity for strengthening or establishing global, regional and national institutions and networks, as well as a potential entry point for the coordination of efforts. Along with an increased focus on strengthening or establishing networks—such as the CTCN—for climate technologies, and providing an extensive knowledge management system, this framework will further improve opportunities to setting appropriate targets for adaptation technologies and addressing adaptation knowledge gaps in the countries involved.

4.7 CONCLUSIONS

Experience with technologies for adaptation has clearly shown that the more successful transfer and diffusion of adaptation technologies are those that meet a number of human needs in addition to their provision of climate benefits, and are firmly grounded in the broader socio-cultural, economic, political and institutional contexts (Olhoff 2014, Klein *et al.* 2000). Focus should, therefore, be placed on technologies that serve a variety of purposes above and beyond climate improvement. In addition, it is clear that adaptation technologies are needed across all socio-economic sectors.

In consideration of the role of technology, international technology transfer for adaptation is critical. However, based on recent technology needs assessments, it seems that most technologies are already available and often, though not always, available even within a country but with major barriers remaining to their further uptake (see for example Trærup and Stephan 2014). Therefore, it seems that at this point of time, the most important issue is not technology transfer for adaptation as such but more a matter of accelerating the diffusion and uptake of identified technologies—although there are also situations where specific international transfer is critical, for example in the need for new improved crop varieties, water use efficiency techniques, and monitoring systems. Governments can facilitate the flow of technologies within countries, using measures such as incentives, regulations and the strengthening of institutions. At the same time, as noted by UNFCCC (2009), the development and transfer of technologies should occur mainly in the context of the implementation of adaptation projects and programmes, and the main sources of financing are expected to come from adaptation funding sources, such as the Green Climate Fund.

Research and development have a significant role in adjusting existing technologies to local conditions, and also in terms of innovation in areas where existing technologies—such as insurance solutions, high yielding crop varieties, or water use efficiency appliances—are insufficient to meet fundamental adaptation challenges. The sharing of experiences by countries when it comes to such innovations to promote the transfer, replication and scaling up of technologies will contribute substantially to closing the adaptation technology gap in countries facing similar challenges. Technological change is treated by some as being caused by institutional change (Koppel 1995). In this sense, institutional strengthening is crucial for producing innovations leading to advanced technologies. It is therefore of great importance to increase the mandate and knowledge of existing and new institutions to include the development, transfer and diffusion of adaptation technologies.

The adaptation technology gaps presented in this chapter increase our understanding of countries' needs for technologies in their efforts to reduce the risk to climate change. Nevertheless, more and improved studies on technology options—their ability to reduce climate risks and their associated costs—are necessary for local (national) prioritization.

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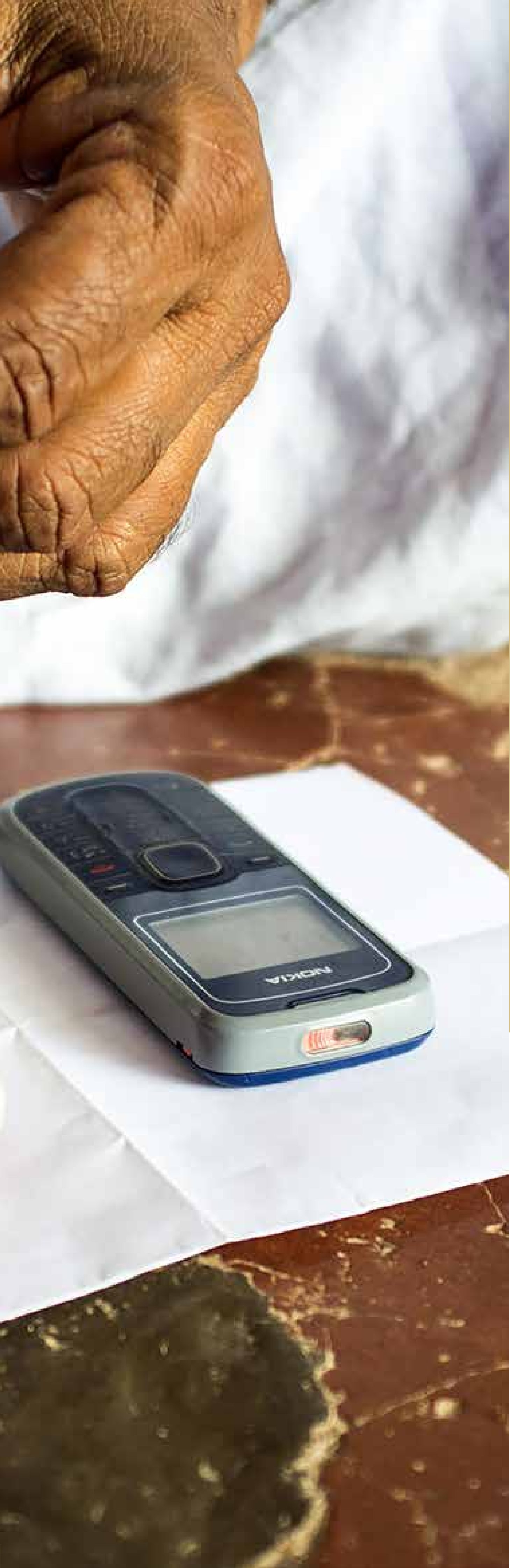

CHAPTER 5

KNOWLEDGE GAPS IN ADAPTATION

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5.1 INTRODUCTION

There are many knowledge gaps in adaptation. Practitioners and stakeholders in developed and developing nations continue to identify knowledge gaps as an adaptation constraint (Klein *et al.* 2014). There is, however, plenty of adaptation knowledge available, which can be integrated, transferred and used more effectively. These aspects are also emphasized in the discussions towards the 2015 climate change agreement, with many Parties calling for modalities for strengthened knowledge production, management and sharing under the UNFCCC. This chapter focuses on three key types of adaptation knowledge gaps that, if addressed, could have considerable potential both in the short- and long-term to contribute towards reducing the overall adaptation gap as defined in Chapter 2. While the contribution of knowledge to bridging adaptation gaps is difficult to quantify, it would be possible to set specific and measurable targets to address knowledge gaps in adaptation.

The first type relates to gaps in our current knowledge base and the related need for knowledge production. It includes an extensive range of widely referenced challenges, such as inadequate data as well as issues concerning data resolution and incomplete information. It also relates to the lack of theoretical frameworks, measurable variables, indicators, factors and drivers, and a repository of adaptation options.

The second type of gap is the weak or missing integration of different bodies of knowledge. Even with existing knowledge, the use of relevant information from diverse sources and across disciplines to address climate change risk, all too frequently fails to happen. Problems of integrating information or knowledge from the natural and social sciences, from expert and local communities, and from researchers and practitioners, pose a critical gap in knowledge.

The third category of gaps is the limited transfer and uptake of existing knowledge by decision-makers at different levels who make choices about adaptation options. Table 5.1 provides examples illustrating the three types of knowledge gaps.

Table 5.1 Examples of different types of knowledge gaps and ways to bridge them

Type of knowledge gap	Example	Gap	Bridging the gap	Sources
Knowledge production	**Coastal adaptation:** Geoscientists are using simulation modelling techniques to recognize coastal behaviour helpful for understanding the risks posed by sea-level rise. There is a reasonable amount of information available on coastal environment and geology at millennial timescales, but scientific understanding on policy-relevant decadal and century timescales is currently limited.	Uncertainties associated with magnitude and rate of sea-level rise. Lack of adequate data and methodologies for quantifying impacts. Assessments and data not available at spatial and temporal scales relevant for policy-makers.	Increase availability of high resolution spatial data and observational data. Improve measuring and monitoring networks. Enhance the understanding of biological processes and levels of acceptable risk. Study past coastal changes to project for the future.	Kettle 2012 Woodroffe and Murray-Wallace 2012
Knowledge production and integration	**Understanding vulnerability and underlying stressors:** Studies from Mozambique and other developing countries connecting climate change, poverty, and development highlight the complex, multifaceted and context-specific nature of the interaction between the three. But little attention is given to resilience building among vulnerable communities.	Vulnerability is a dynamic and interactive phenomenon and cannot be captured in linear models. Most analysis is place-based, and cross-scale analysis of the impact of direct and indirect channels of climate change on multidimensional poverty is limited.	Develop theoretical connections between poverty, development and limited resources in a changing climate. Increased focus on understanding factors that enable response and recovery, and empirical research on avenues of impact beyond food and agriculture.	Leichenko and Silva 2014 Ericksen 2008
Knowledge integration and transfer and uptake	**Communicating climate information:** Combining 'Kiganda' style[1] of participation with Western approaches worked with traditional hierarchies of a group of African farmers in Uganda, supporting collective identity and consensus building, and enabling group members to exercise their agency in framing solutions.	Application of existing knowledge at local scale depends on how scientific information is perceived and the style of participation used to make decisions by multiple stakeholders. Knowledge about various styles of participation and communication of uncertain climate information is limited.	Knowledge of ethnographic and sociolinguistic methods of communicating about climate change with specific communities is a useful tool that can facilitate knowledge transfer and uptake.	Roncoli *et al.* 2010 Roncoli 2006

The knowledge production/integration/transfer approach[1] encapsulates key ways in which knowledge can contribute to bridging adaptation gaps. Efforts to expand the knowledge base to answer critical questions that inform adaptation continues to be a priority, but reducing gaps in the knowledge base in isolation does not ensure that adaptation actions will be undertaken (Klein *et al.* 2014). Disconnections—and inefficient or ineffective use of existing knowledge—must also be addressed. The challenge with knowledge gaps, therefore, is to produce and integrate knowledge from multiple sources incorporating the perspectives of various stakeholders, and allow for the smooth access and uptake of relevant information by decision-makers at different levels for effective adaptation policy, planning and implementation.

1 Kiganda style of participation is based on the intricate culture prevalent in Uganda that "emphasizes the importance of affirming ties to a collectivity, respect for social hierarchy, deployment of good manners, and consensus building" (Roncoli *et al.* 2010).

5.2 KNOWLEDGE PRODUCTION

Knowledge to support adaptation planning and its implementation is needed by different users, such as policy-makers, planners, practitioners and local communities, at different levels from local to global. The gaps in the knowledge base that need to be addressed for effective and sustainable adaptation, therefore, are context specific, varying between user groups and geographic locations. Some of the most commonly cited information and knowledge gaps that could be bridged in the short run concern the performance or effectiveness of various adaptation approaches and cost–benefit analysis of adaptation options and the comparisons between them. Another area of significant potential is that of addressing uncertainty about the future impacts of climate change and in particular the interactions between climate change and socio-economic systems and trends. These knowledge gaps are discussed in more detail in the sections below. Annex C (available online) summarizes adaptation knowledge gaps and research priorities identified in selected studies.

5.2.1 ASSESSING ADAPTATION APPROACHES

Climate change adaptation is occurring along with all the other adjustments taking place in response to changes in the environment, as well as development processes and political and social changes. Methodologically, it is challenging to distinguish where and how much climate change related adaptation is occurring on a local and regional scale (Lobell 2014, Merilä and Hendry 2014). The performance or efficacy of any adaptation approach or technique is difficult to assess because of the confounding effects of other development, socio-cultural and environmental processes also taking place (Cramer *et al.* 2014). These are on top of the already uncertain nature of the impact of climate change.

Efforts are being made by the scientific community to develop quantitative methods for documenting changes in baseline trends due to climate change, as well as the cost and scope of adaptation options (Challinor *et al.* 2014, Porter *et al.* 2014, Rojas *et al.* 2013). However, broader studies on adaptation techniques adopted to deal with reduced crop production, for example, or increased losses from drought are sporadic and scattered, and often relevant only for a specific context. As discussed in Chapter 3, the evidence base around the costs and benefits of adaptation remains fragmented, with limited comparability between studies. Systematic assessments of studies and findings in these areas thus have the potential to expand the knowledge base needed to support decisions.

Box 5.1: Monitoring and evaluation of adaptation to climate change in Colombia

In Colombia, a comprehensive integrated national monitoring system and protocol for adaptation to climate change is being developed as an instrument for reliable information to monitor and evaluate adaptation activities in different economic sectors, regions, and cities. The initiative is to be led by the Ministry of Environment, with technical and financial support provided by the Climate Technology Centre and Network (CTCN *forthcoming*).

An important aspect of the project is the development of appropriate indicators to track progress on adaptation. These will be based on the needs identified as a part of the Colombian policy on Adaptation to Climate Change, as well as on actions identified for monitoring within the National Plan for Adaptation to Climate Change (PNACC). A comprehensive review of indicators used in past and current adaptation activities will be used as the departure point.

The project is framed around a number of key expected results that could inform monitoring and evaluation efforts in other countries, as well as under the UNFCCC. These include: the drawing up of a vulnerability baseline in Colombia and verifying the level of compliance in line with the country's vulnerability and risk reduction goals; the monitoring and evaluation of the performance of adaptation projects, and assessment of the need to make adjustments; the assessment of the level of regional vulnerability, allowing the incorporation of climate change variables into a wide set of environmental, territorial and sectoral planning instruments, and allowing comparative analysis between regional and sectoral projects, as well as an assessment of the feasibility of development projects; and producing standardized and systematic inputs for National Communications and for the Biennial Reports that Colombia must present to the UNFCCC as part of its international commitments.

Box 5.2: Long-term scenario planning for adaptation

Designing effective medium- to long-term adaptation requires projections of how the climate will change, including potential changes in the frequency and intensity of extreme weather and climatic events, and how development patterns could alter the exposure and vulnerability of the human or natural system to these changes. The emphasis of research and modelling has been on providing increasingly fine-scale temporal and spatial projections of the magnitude and pattern of climate change. There has been less research and modelling on understanding the range of possibilities of future development, what these mean for exposure and vulnerability, and how these could interact with climate change to alter risks. Many studies projecting the risks of climate change include only demographic change and changes in economic growth as determinants of vulnerability, effectively assuming that changes in other factors will have a limited influence on future risks. It is highly unlikely that all other factors will remain the same over coming decades. Such projections often consider only a limited range of possible futures, meaning adaptation choices are not being informed by the full range of possible futures.

In a recent effort to address this gap, the emission-forcing pathways (the Representative Concentration Pathways or RCPs) have been combined with the socio-economic development pathways (Shared Socioeconomic Pathways or SSPs) (Ebi *et al.* 2014, Kriegler *et al.* 2014, O'Neill *et al.* 2014, van Vuuren *et al.* 2014). Socioeconomic factors considered in the SSPs include aspects of socio-ecological systems, such as demographic, political, social, cultural, institutional, lifestyle, economic, as well as technological variables and trends. How each of these domains evolves over coming decades will affect the resilience of future societies and the options available to prepare for—and manage—climate change risks. Also included is the human impact on ecosystems and ecosystem services, such as air and water quality, and biodiversity.

More generally, there is a lack of systematically collected data that can be used to study adaptation and to optimize it at different levels. Information about the current status of adaptation experience is prerequisite to planning adaptation for the present and the near future. Evidence on adaptation is mostly available at the micro scale and, while useful at their respective community, municipal or regional scale, these findings have limited use in informing a global-scale adaptation framework. Micro-level studies often have incomparable methodologies with different sets of objectives, theoretical standpoints and assumptions—hence the scope for transferring knowledge from one local scale to another is often limited (Hulme 2010, Poteete and Ostrom 2004).

All of the above, as well as the recent emphasis by several Parties on the importance of the review of effectiveness of adaptation action under the 2015 agreement, underlines the need for coordinated efforts related to the monitoring and evaluation of adaptation. Monitoring and evaluation are separate but closely linked processes: monitoring reports on an ongoing basis on the progress made in implementing an adaptation initiative; evaluation is an independent assessment of how effective the initiative was in bringing about the desired change and how that change came about. Lessons learned from monitoring and evaluation can guide mid-course adjustments of adaptation initiatives through adaptive management, and contribute to the evidence base and learning on which approaches to adaptation are considered effective—thus addressing key gaps in adaptation knowledge. When adaptation planning and implementation are based on continuous learning, there is scope for the capacity to adapt to gradually improve (IEG 2013). Box 5.1 provides an example of a new ambitious initiative in Colombia aimed at developing and implementing an integrated national monitoring system.

5.2.2 ADDRESSING UNCERTAINTY

The demand for more information and the strengthening of a knowledge base is often precipitated by concerns regarding decision making and uncertainty about the future (Klein *et al.* 2014). Chapters 2–4 of this report discuss the challenges arising from uncertainty over future climate change impacts and the evolution of socio-economic systems for framing an adaptation goal, as well as for estimating the costs and benefits of adaptation and investing in adaptation technologies. Implementing adaptive management approaches and no-regrets adaptation options can facilitate adaptation to an uncertain future. At the same time, thinking about adaptation in the long-term can benefit from having a vision of possible futures and some indication of how socio-economic and related trends will evolve in the next few decades. One of the key tools for addressing

uncertainty is using scenarios, which describe how the human-environment system could evolve over time. Box 5.2 outlines an effort to use scenarios to address knowledge gaps around the interaction of development choices with climate change, in order to design better adaptation options that are more robust to a range of plausible futures.

5.2.3 RESPONDING TO USER NEEDS

Effective decision support begins with an understanding of user needs, which is often developed collaboratively and iteratively among users and researchers (National Research Council 2009). It is important to ensure that the knowledge produced responds to user needs and identified knowledge gaps, and is relevant and usable for decision-making and action. However, only a limited number of initiatives have focused specifically on identifying adaptation knowledge needs, especially at the regional or sub-regional level. Box 5.3 describes one such initiative developed for identifying, prioritizing and addressing adaptation knowledge gaps. The identification of the stakeholders' knowledge needs should be integrated more explicitly into project framing and design, rather than only taking place retrospectively at the end of the project cycle in the identification of experiences and of lessons learnt.

Finally, it has been observed that the practice of adaptation has outstripped the rate at which relevant peer reviewed research can be produced and disseminated (Noble *et al.* 2014). Activities that bring practitioners and researchers together to solve problems, to learn by doing and co-generate knowledge, therefore play an important role in addressing adaptation knowledge gaps and are most likely to lead to practical, usable knowledge (van Kerkhoff and Lebel 2006). These aspects are further addressed in the following sections.

Box 5.3: Pilot adaptation knowledge gap initiative in the Andes region

To address the need to better align supply and demand for adaptation knowledge, and to respond to adaptation knowledge gaps, the UNFCCC secretariat is collaborating with UNEP through its Global Adaptation Network (GAN), to develop and implement an adaptation knowledge initiative. The objective of the initiative is to prioritize and catalyse responses to strategic needs in adaptation knowledge.

The initiative provides a systematic and credible approach to identifying and prioritizing tractable and strategic adaptation knowledge gaps that can be addressed through the repackaging and/or dissemination of data, information and knowledge. This is done through a scoping exercise and a literature review by a consultant, the organization of a priority setting workshop, synthesis of the outcomes for catalysing response action, and finally through monitoring the implementation processes.

A pilot phase was carried out in 2014 in the Andes region where a multidisciplinary stakeholder group has been established to consider the pool of knowledge gaps arising from the scoping exercise. During the priority-setting workshop, the stakeholders applied prioritization criteria, which produced a credible list of tractable strategic knowledge gaps. The process of prioritizing the knowledge gaps is the core activity that differentiates this initiative from other assessments that have identified adaptation knowledge gaps, but have done so without a well-defined and rigorous methodology that ranks gaps based on transparent criteria. The three most important knowledge gaps identified by the group were: 1) integrated research on the effects of climate change on ecosystem services and their relationship with quality of life, 2) mechanisms for including adaptation in current planning tools, and 3) data and information on health and associated variables, and on the impact of climate change on health in the region.

The multidisciplinary stakeholder group also undertook a preliminary identification of possible responses to address the prioritized knowledge gaps and target institutions that could implement such responses. Conveners will subsequently undertake efforts to catalyse the implementation of the relevant response actions to address the knowledge gaps and replicate the initiative in other regions and thematic areas.

5.3 KNOWLEDGE INTEGRATION

The challenge of climate change is multifaceted and has non-linear impacts in all realms of environment and society. Understanding the problem itself, its meteorological and ecological implications, and how these changes are interacting with and affecting socio-economic systems and more broadly human welfare, is an enormous challenge. Researchers, practitioners and local communities are observing and addressing these impacts. Though the underlying philosophies, methodologies, perspectives, objectives, and audiences are different, the findings are all critical parts of the jigsaw puzzle. It is important to explore ways to align and integrate these different bodies of information to design successful plans for adaptation.

Primary gaps in knowledge integration involve connecting environmental and human dimensions, bridging scales and producing policy-relevant data and knowledge. The study of socio-ecological systems that have measureable and non-measurable components is particularly challenging. The social science disciplines employ a mixture of quantitative and qualitative techniques and critical approaches to produce socially relevant knowledge on society and its interaction with the environment. The approach towards building this knowledge emphasizes spatial and cultural diversity and, in many cases, is considerably different from the standardized statistical tools supporting large-scale comparisons traditionally employed in the physical and natural sciences.

Bridging across different communities of practice can also be challenging. For example, although there is a considerable overlap between the work of climate change adaptation and disaster risk reduction communities, there are spatial, temporal and functional scale mismatches, inconsistent definitions of terms and concepts, and weak links between data and the knowledge these communities have produced (Birkmann and Teichman 2010).

Borrowing theoretical perspectives from different disciplines to unpack some of the challenges of climate change has become common. The role of governance systems that operate on collective action issues on many levels from small to large has been explored to understand complex issues surrounding the global governance of climate change, ocean acidification and the loss of marine biodiversity. Some mechanisms used by public governance systems on different scales—such as information sharing for coordinated action and conflict resolution—are found to operate at an international level through the interplay between individuals, international organizations, and their collaboration patterns (Galaz *et al.* 2012). Studying, supporting, and learning from collective action undertaken by multiple units to address climate change risk on many levels have been suggested, in addition to the global efforts (Ostrom 2010).

5.3.1 CONNECTING DIFFERENT BODIES OF KNOWLEDGE

Connecting the work of academics and practitioners, as well as the knowledge of local communities, poses specific challenges. The audiences and discourse of these communities are often different: the study of consultation processes in urban areas, such as Lima in Peru, shows that even in a participatory set-up, skewed results that reflect the interests/voices of dominant stakeholders can emerge (Miranda Sara and Baud 2014). At the same time, an examination of the implications of plausible climate change scenarios for water governance in the same urban areas showed that, with political will, knowledge can travel easily in hybrid networks connecting different researchers, practitioners and institutional communities and other stakeholders (Miranda Sara and Baud 2014). Different methods of data collection and framing or conveying knowledge about the interaction between society and environment can, however, result in limited agreement in the knowledge produced (Williams and Hardison 2013, Gearhead *et al.* 2010). Observations made by local indigenous experts and wind-pattern readings from local stations in Clyde River, Nunavut, showed inconsistency because the areas covered by the two sources were usually different. The method and parameters of measuring wind patterns change over time (for the Inuit's observations, for example) and are therefore not comparable over time. The Inuit observations are not limited to wind speeds but also cover the implications of these speeds on safety and travel, whereas research station data does not cover the impact of wind speed on any other factor (Gearhead *et al.* 2010).

One of the major issues in adaptation knowledge integration has been the development of comprehensive methodologies for addressing climate risks, aligning philosophies to integrate knowledge from positivist and interpretive research paradigms, as well as scientific, traditional and practitioner communities (Moss *et al.* 2001). Box 5.4 describes one approach for integrating scientific and traditional knowledge in adaptation planning. On a larger scale, adopting comparable methods to measure vulnerability, develop indicators and establish widespread monitoring systems have been suggested by some (UNEP 2013). Others have suggested linking top-down and bottom-up approaches for vulnerability assessments (Mastrandrea *et al.* 2010). Broader discussion on integrating adaptation knowledge from different bodies of work with the adaptation literature has suggested new coupled knowledge theories and descriptions of knowledge; the imperative for better understanding the process of public policy making before setting research agendas; the need for transformation and open knowledge systems that allow societal agenda setting; collective problem framing; and the integration of multiple perspectives and sources of knowledge (Pahl-Wostl *et al.* 2013, Tabara and Chabay 2013, Franca Doria *et al.* 2009).

Box 5.4: Bringing together traditional local and scientific knowledge for participatory scenario planning

Combining local and scientific knowledge systems is important for making climate information locally relevant and empowering for communities. Rural communities have an intimate interaction with the climate on a local scale, directly experiencing change as it occurs and drawing on traditional knowledge for short-term to longer seasonal forecasts. With the changing climate, however, community knowledge on climate is faced with new challenges and limitations. This is the entry point of scientific climate information. Meteorological seasonal forecasts provide information about the probability of different amounts of rainfall and the timing of onset and cessation of rains for different climatic zones in a country. They can also include possible rainfall distribution over time and space within the season. Although the accuracy of these forecasts is improving over time, they are still limited in forecasting climate at local scales.

Participatory Scenario Planning (PSP) is a method pioneered by the Adaptation Learning Programme (ALP), implemented by CARE International for collective sharing and interpretation of seasonal climate forecasts. The PSP method brings together meteorologists, community members, local government departments and NGOs to share, understand, interpret and communicate climate information, and creates a space for dialogue on local adaptation issues and options. Participants at a PSP forum consider the probabilities given in the seasonal forecast, assess their likely hazards, risks, opportunities and impacts, and develop scenarios based on such an assessment. They discuss the potential implications of these scenarios on livelihoods in relation to a review of current food security and health, taking into account local capacities, resources and institutional linkages (among other factors).

This leads to the participatory development of advisories that give locally relevant options for responding to identified opportunities and levels of risk and uncertainty. The options are tailored to different livelihoods for use in decision making and planning for the coming season. Advisories are communicated to local communities, NGOs and government ministries, and departments through community and religious leaders, community representatives, government extension services, local NGOs, radio stations and other media.

PSP is now being adopted by national meteorological services, agricultural ministries, and local governments, with CARE and other NGOs in Kenya, Ghana, Niger, Ethiopia and Malawi. While it is one approach filling the gap on the integration of local and scientific climate knowledge, the process has raised other gaps concerning knowledge production, integration and diffusion. These include the need for the inventories and validation of local knowledge; the systematic communication of end-user information needs and the development of climate products that respond to these; the production and analysis of downscaled climate data over time and its integration with local knowledge; and the integration of knowledge sources around short-range and long-term climate projections, in addition to seasonal forecasts.

5.4 KNOWLEDGE TRANSFER AND UPTAKE

Often the most important knowledge gap for private and public decision-makers (including policy makers, managers, planners and practitioners) is not the lack of information on climate change and adaptation, but the need for better-filtered, synthesized and accessible information (for example, Hanger *et al.* 2013, Tribbia and Moser 2008). There are functional, structural, and social constraints that make a significant amount of knowledge produced by scientists inaccessible or unusable. The successful application of existing knowledge depends on communication between researchers and decision-makers, the effective tailoring of knowledge to the specific context and constituency, and its translation into formats or languages required by decision-makers.

The missing links between theory, policy, and practice is not a recent challenge (Patwardhan *et al.* 2009). Some contexts require the transfer of knowledge (for example, climate services), while others require the integration of adaptation research frameworks within the working domains of policy-makers to produce socially relevant information for their use. Boundary organizations, which act as intermediaries between science and policy, play an important role in climate change knowledge transfer and communication, including

Box 5.5: Bridging the gap between knowledge producers and users

Countries across the industrialized and developing worlds are making a concerted effort to enhance the uptake of downscaled climate model information in adaptation planning and related decision making. Identifying the needs of climate information "users" such as decision-makers is not easy, though. Many decision-makers operate in a highly complex decision space and are often unaware of the role of climate in these contexts. Decisions are seldom made in isolation and usually have to consider multiple sectors, locations and stressors that are interlinked and interdependent (Vogel and O'Brien 2006).

Climate data is largely being fed into this decision making space through a supply driven process, as is made evident by the recent proliferation of portals and tools purporting to provide a climate data "answer" in the form of a single method, model or tool. Often this answer is stripped of vital information about the skill and robustness of the climate data product, and users lack the capacity to evaluate whether the climate data can be appropriately applied to decision making (UCL 2014, Lemos *et al.* 2012). This combination of factors—an oversupply of questionable climate data and an under-capacity to disambiguate information content—creates the potential for maladapted decisions and actions.

Lessening the persistent discontinuities between climate modellers and constituencies that increasingly rely on climate information for adaptation planning requires a "co-exploration" approach to using climate data. Successful co-exploration entails engaging a full complement of user groups (from modellers to policy-makers) in defining the decision making space into which climate model data is required, and evaluating the robustness and relevance of that data in the context of actual decisions to be made (UCL 2014).

Such an approach was recently developed by the University of Cape Town's Climate System Analysis Group, in collaboration with START. This co-exploration approach emphasizes: the use of relevant and appropriate climate data that intersects with key end-use contexts (vulnerabilities, policy development, decision making and so on); building understanding and awareness of user communities as to the limits of climate model predictability in time and space; and building understanding and awareness of climate scientists and modellers for information needs and decision making contexts in order to better focus and inform their work.

In 2013–2014, the co-exploration approach was tested in two workshops with urban decision-makers across six African cities (Accra, Addis Ababa, Dar-es-Salaam, Kampala, Lusaka, and Maputo) involving a cross-section of participants from academia, government and civil society. The methodology features a step wise process that involves identifying key elements related to urban livelihoods, infrastructure and services, first, before identifying important non-climate stressors that are exacerbated by climatic stressors, followed by a layered application of climate projections information. Adaptation options are identified at key junctures and evaluated against the messages of future change contained in climate projections, also identifying where uncertainties and contradictions exist in the climate data.

The two workshops with urban decision-makers have produced rich insight into the co-exploration process, demonstrating good potential for scaling up. The approach was successful in that it engendered critically needed learning spanning climate modellers and climate data user groups. This success can be partly attributed to the layering and gradual accumulation of information, which reduced the perceived complexity of information being shared, and allowed exercises to be modified in response to new insights from different sectors, stakeholders or city contexts. Moreover, this approach clearly articulated important areas where non-climate and climate stressors interact to exacerbate vulnerabilities related to infrastructure, services and livelihoods, thus providing a more contextualized and targeted basis for applying climate data.

An important barrier observed in this multi-disciplinary setting was the low baseline knowledge of sectoral experts with respect to climate model terminology and concepts. A more generic barrier concerned the systemic problem of how to sustain engagement after the end of a workshop. Adaptation funding tends to be

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short-term, compartmentalized and project-driven, which is antithetical to building a community of practice around co-exploration. The risk of this approach is that repeated one-off engagement with participants groups fails to build enduring trust and collaboration.

The co-exploration approach is quite flexible and is readily transferrable to a variety of situations where climate data is needed. With trained and careful facilitation and sufficient resources for continuing the engagement, the co-exploration approach can be sustainable. Such an effort would involve early and continuous collaboration with local actors; iterative engagement of place-based experts: extensive examination of climate projections data; anchoring of the case study in actual and active policy contexts; and a strong focus on capacity building outcomes that would ultimately enable the approach to be replicated by locally-based teams.

translation, engagement and knowledge exchange (Jones *et al.* 2014).

The approach of risk management and the process of iterative learning cycles based on past experience, constant monitoring, measuring and improving the capacity to act, and scenario planning, are all proposed for the setting-up of an empirical and experimental basis for adaptation actions (IPCC 2012, Tschakert and Dietrich 2010). This requires providing a complete set of information to decision-makers rather than just the growing list of adaptation options. Decision-makers need information on, for example, the climatic conditions under which specific adaptation options would function, the types of benefits that could be expected from different adaptation strategies, and the institutional structures required to continue these efforts (Weichselgartner and Kasperson 2010, Patwardhan *et al.* 2009). This entails a coordinated approach to the collecting and sharing of information, with clearly identified roles and responsibilities.

Limitations in the capacity to use available data and information are one of the challenges in bridging research, policy, and practice. Decision-makers need reliable climate observations, as well as other socio-economic and environmental data, to assess their climate risks and vulnerabilities and to understand how these change over time. Framing and communicating the inherent uncertainty of climate change projections, impacts and adaptation options are a major challenge in this context (Hanger *et al.* 2013, Stockholm Environment Institute 2013). Efforts at co-exploration are being made to bridge the gap between scientists and policy-makers, to improve coordination and understanding of constraints in both domains (see Box 5.5). More experimentation is required to understand this process and develop easy channels of communication or interaction space between knowledge producers and potential users in different contexts.

5.5 CONCLUSIONS

Knowledge gaps are often identified as one of the key adaptation constraints by practitioners and stakeholders. The chapter looks at three types of adaptation knowledge gaps that, if addressed, could have considerable potential both in the short- and long-term to contribute towards reducing the overall adaptation gap. These are (i) missing or incomplete knowledge (gaps in knowledge production); (ii) inadequate linkages between different bodies of knowledge (gaps in knowledge integration); and (iii) limited diffusion and translation of knowledge to decision-makers (gaps in knowledge transfer and uptake).

For many regions and countries, the systematic identification and analysis of adaptation knowledge gaps is lacking, and there are few initiatives focused on addressing this. The consideration of knowledge gaps should be integrated more explicitly in project and programme framing and design, involving all stakeholders. This would help ensure that the knowledge produced responds better to user needs and identified knowledge gaps, and is relevant and usable for decision making.

Some of the most commonly cited gaps in the knowledge base that could be bridged in the short run concern the opportunities and constraints of various adaptation options and cost–benefit analysis of adaptation strategies. There is a need for systematic efforts to monitor and evaluate adaptation actions to assess and build an evidence base on their effectiveness. Semi-standardized documentation of project experience to support comparison and effective linking with national plans, objectives, priorities and monitoring processes is critically needed. Collaborative

efforts connecting research, local/traditional, and practitioner communities and other stakeholders at different levels need to be established to address context specific knowledge gaps.

Although there is a clear need for producing new knowledge in certain areas, a considerable body of knowledge on adaptation already exists and could be used more effectively. Integrating such knowledge from different sources and making it available to decision-makers at different levels is arguably the most important knowledge need. Connecting and integrating different communities and approaches is often challenging, and initiatives facilitating this bridging of knowledge systems are urgently needed. To make it accessible and usable for decision-makers, knowledge must also be filtered and synthesized. The successful uptake and use of knowledge requires communication and co-exploration between researchers and decision makers, effective tailoring of knowledge to the specific context and constituency, and its translation into formats or languages required by decision-makers.

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